Mechanics and Final Assembly

November 2, 2000

US ATLAS Pixel Review

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LBNL

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Hytec Inc

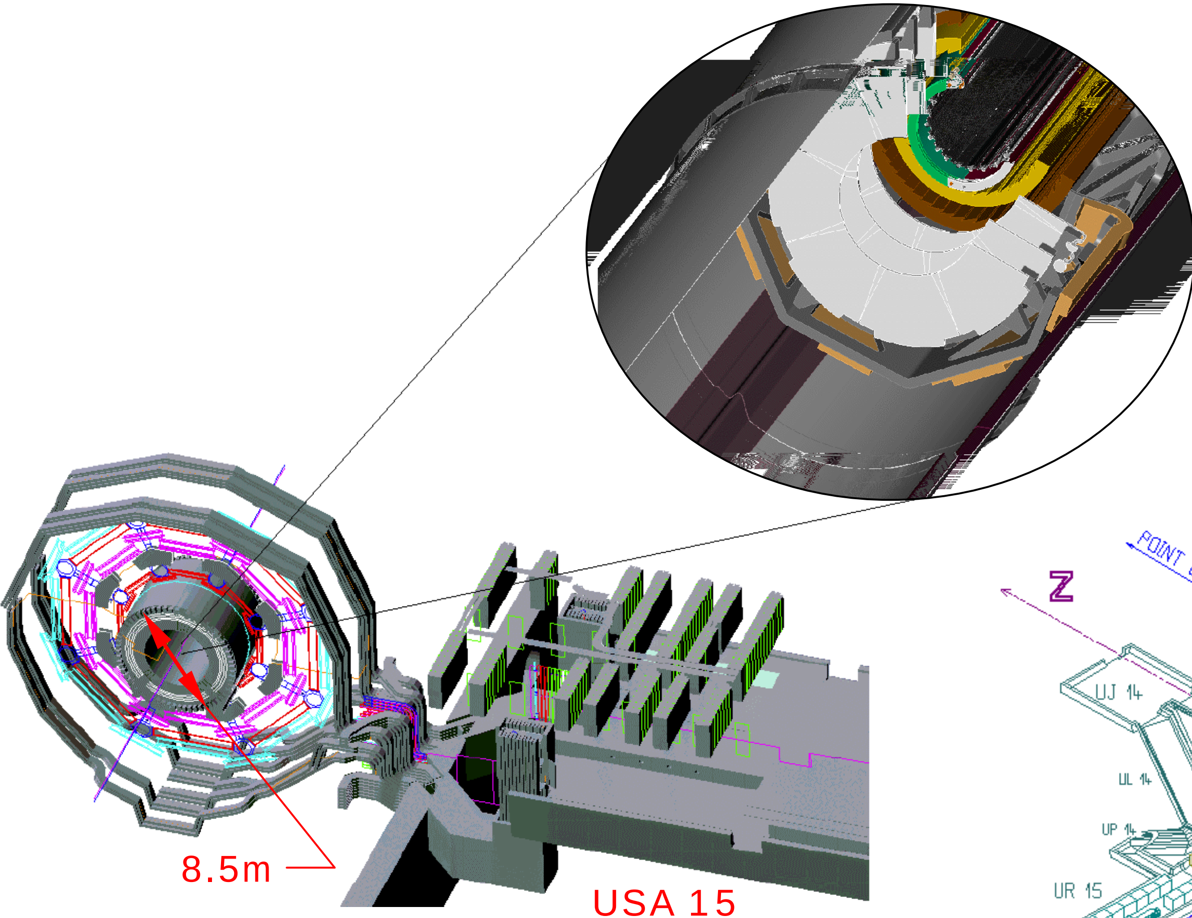
Talk Overview

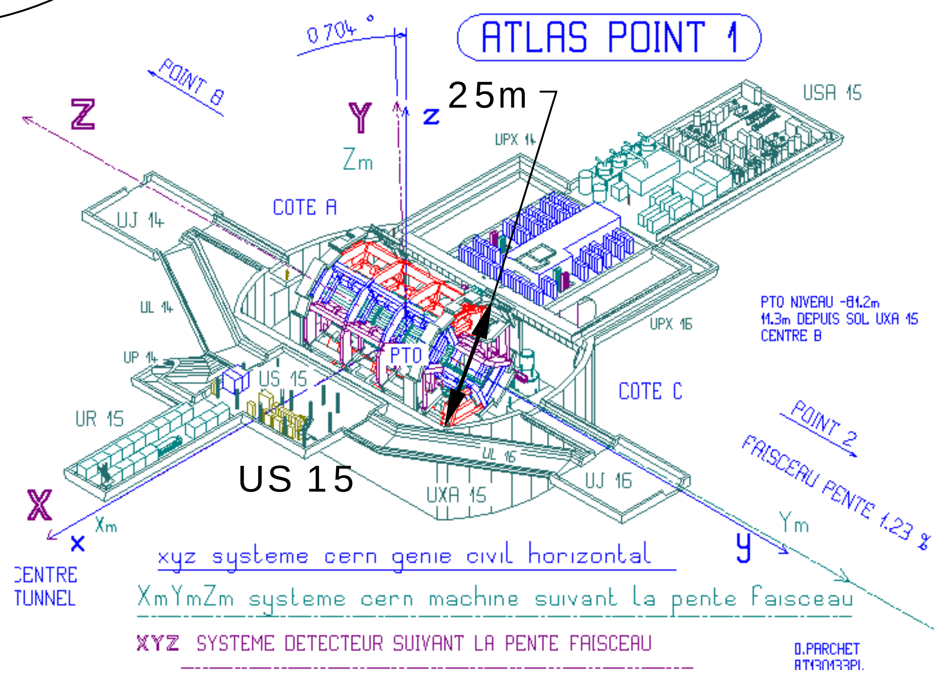
- **Mechanics Overview and Integration**
  - WBS 1.1.1.1 Mechanics and Final Assembly
  - Big Picture of Mechanics of ATLAS
  - Integration Effort--Insertable Pixel System
- **Production WBS 1.1.1.1.3--What we plan to build**
  - Description of items in WBS
  - Technical Background
- **Cost & Schedule**
  - Summary of Costs
  - Schedule

Pixel Detector

Pixels in ATLAS Cavern

Pixels are the innermost of all detectors in ATLAS





Pixel Services have the furthest to go on their way to the racks.

Pixel Detector

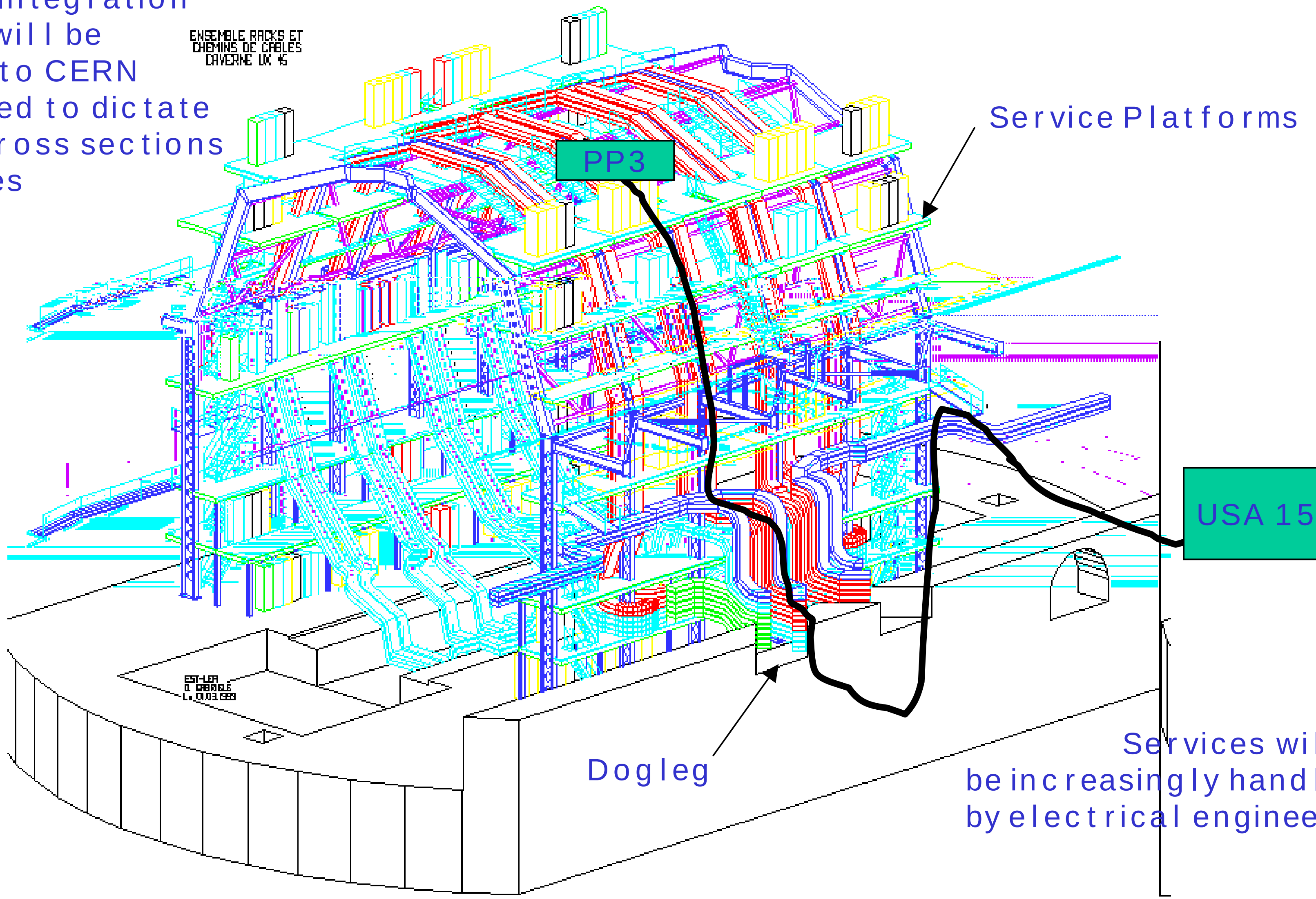
Integration Effort

- **External Services**
  - Cavern and detector level
- **Insertable Pixel Development**
  - Proposed ~7weeks ago
  - Frame resized for workable layout
  - Installation details and structures overview
- **Internal**
  - Services
  - Barrel to Global Support
  - Disks to Global Support

Pixel Detector

Cavern Level Integration

Cavern Integration effort will be shifted to CERN
Still need to dictate cable cross sections and types

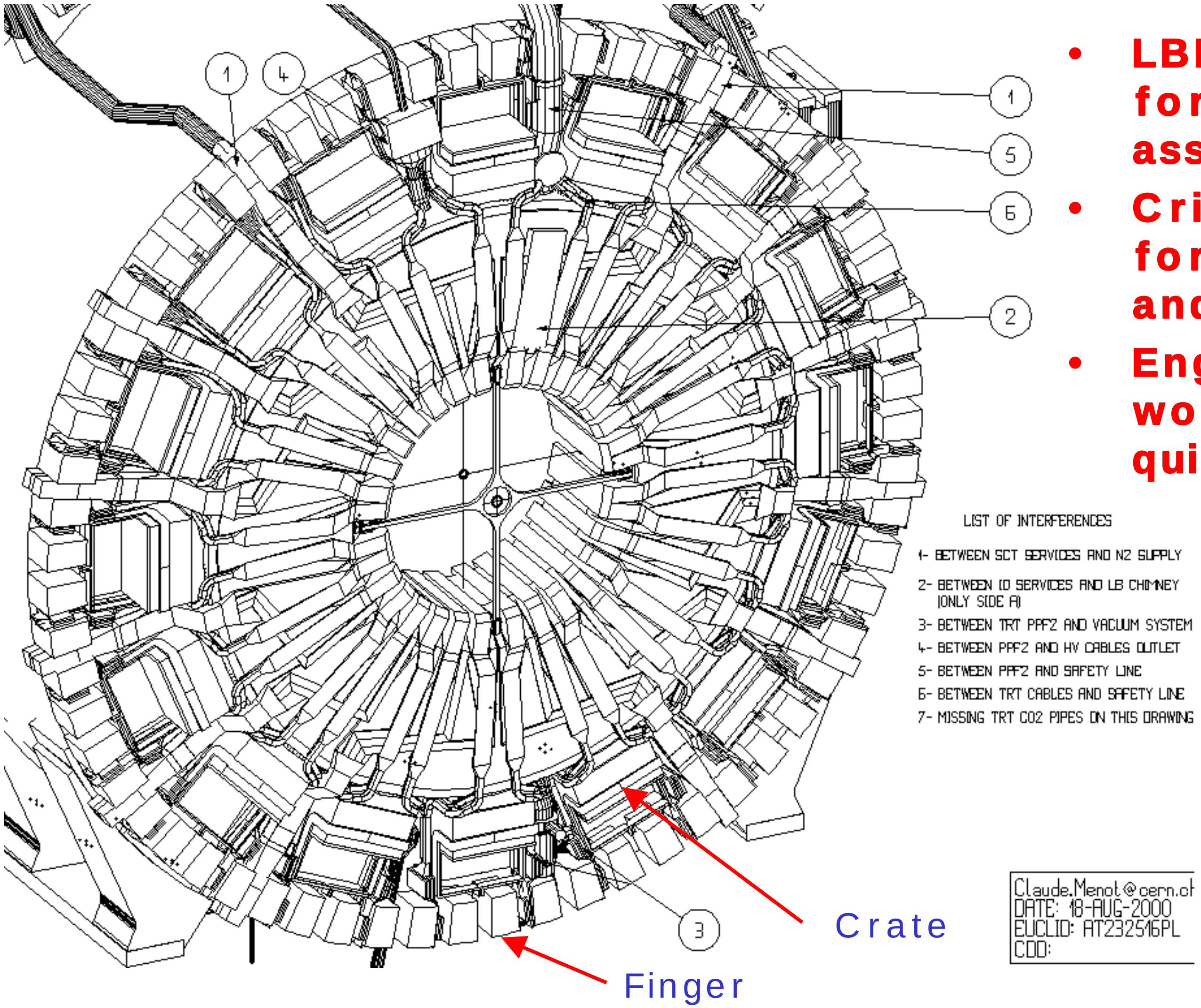


Services will be increasingly handled by electrical engineer

LBNL will be providing 4 rounds of electrical service prototypes--converging on the actual mechanical package

Pixel Detector

Services Through PP2 Region



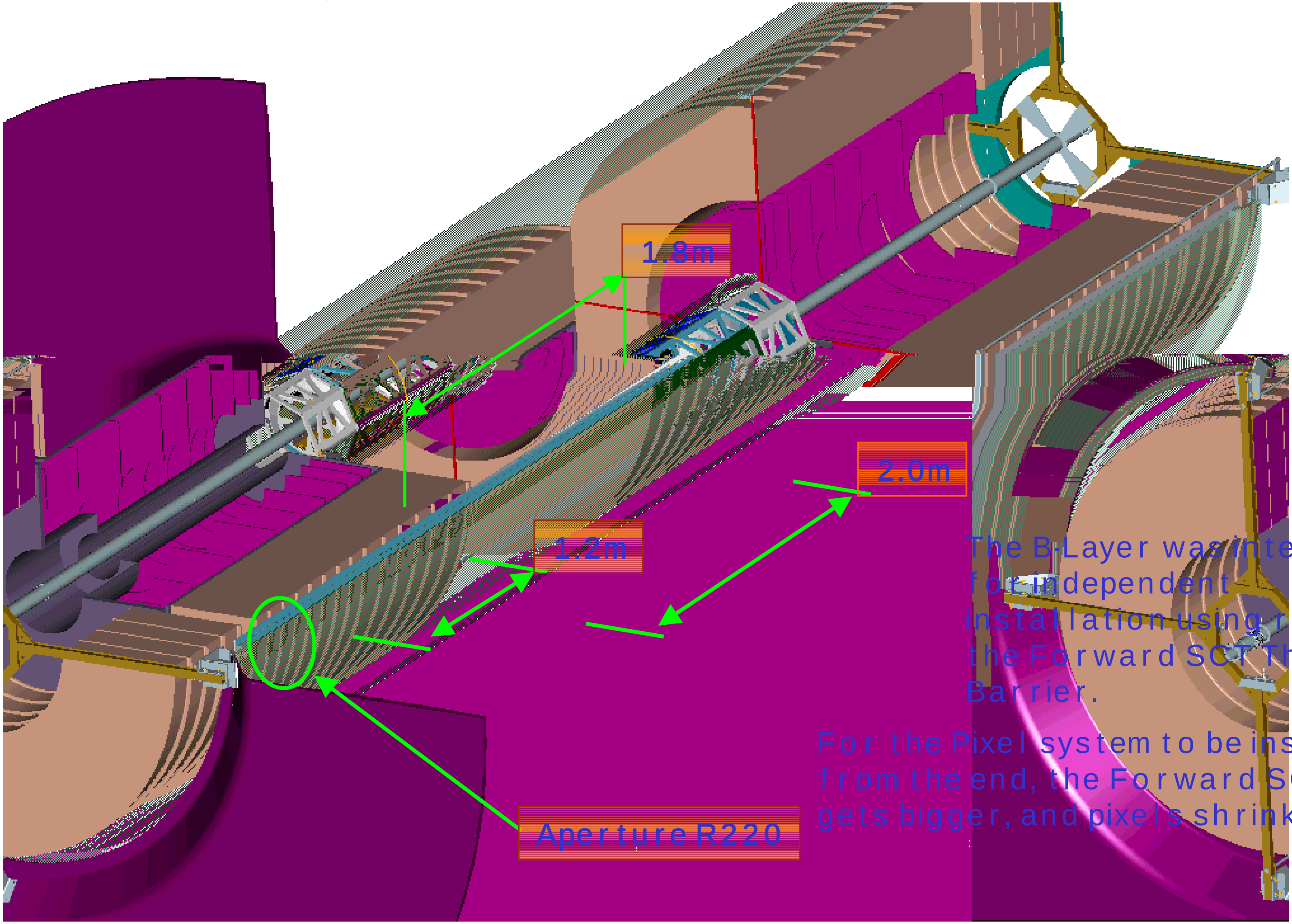
- **LBNL is providing cables for mockup currently assembled at CERN**
- **Critical Area leaving PP2 for PP3 Between Crates and Fingers**
- **Engineers at CERN working to resolve as quickly as possible**

Fully Insertable Pixel system

- **Clam Shell not necessary if Beam Pipe is not contiguous**
  - Short Access configuration does not allow introduction of anything as large as a full Pixel system to the access volume
  - During Long Access configuration Liquid Argon End cap is pulled back and off-axis along with its beam pipe section
- **Clam Shelling of B-Layer (innermost barrel layer) is only necessary to clear Beam Pipe Flange**
  - Propose same B-layer design / dimension and similar support scheme
  - Extend B-Layer installation scheme to entire Pixel Frame
- **Proposal keeps same functional frame elements intact**
  - Global support frame is not clam-shelled
  - Staves and Barrels same in design but smaller
  - B-layer is the same
- **However: Disks and Frame must change parametrically**

Pixel Detector

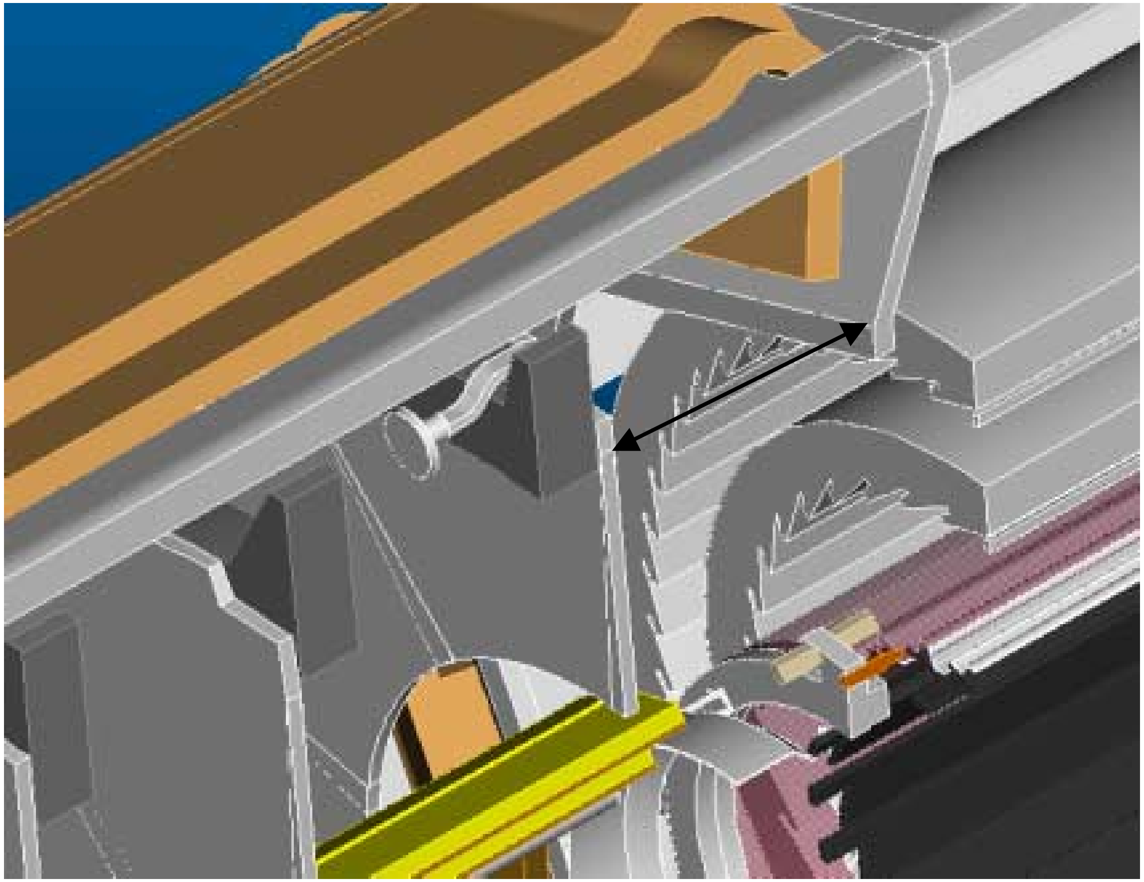
Old Layout of C-Side of Inner Tracker



How Big is the Pixel Frame

- **Model of Insertable Pixel generated using parametric modification of existing parts**
  - layout rules for sectors same as current sector, but with less modules
  - Frame Layout assumes same joint geometries, with more narrow panels
  - Layout of frame was scaled to an 8-sector disk
- **Disks are laid in for 3hit coverage Disk Service routing on the inside of the frame determines how small the frame can be**
  - Minimal disk size is 8-sector disk--any smaller does not allow B-layer installation
  - a 9-sector disk in the first position is desirable to improve coverage
    - layouts with all 8-sector disks were evaluated--this is the frame size required for an all-8-sector layout as well
    - a 9 is possible only in the first position with a modified cooling tube exit

Service routing defines envelopes

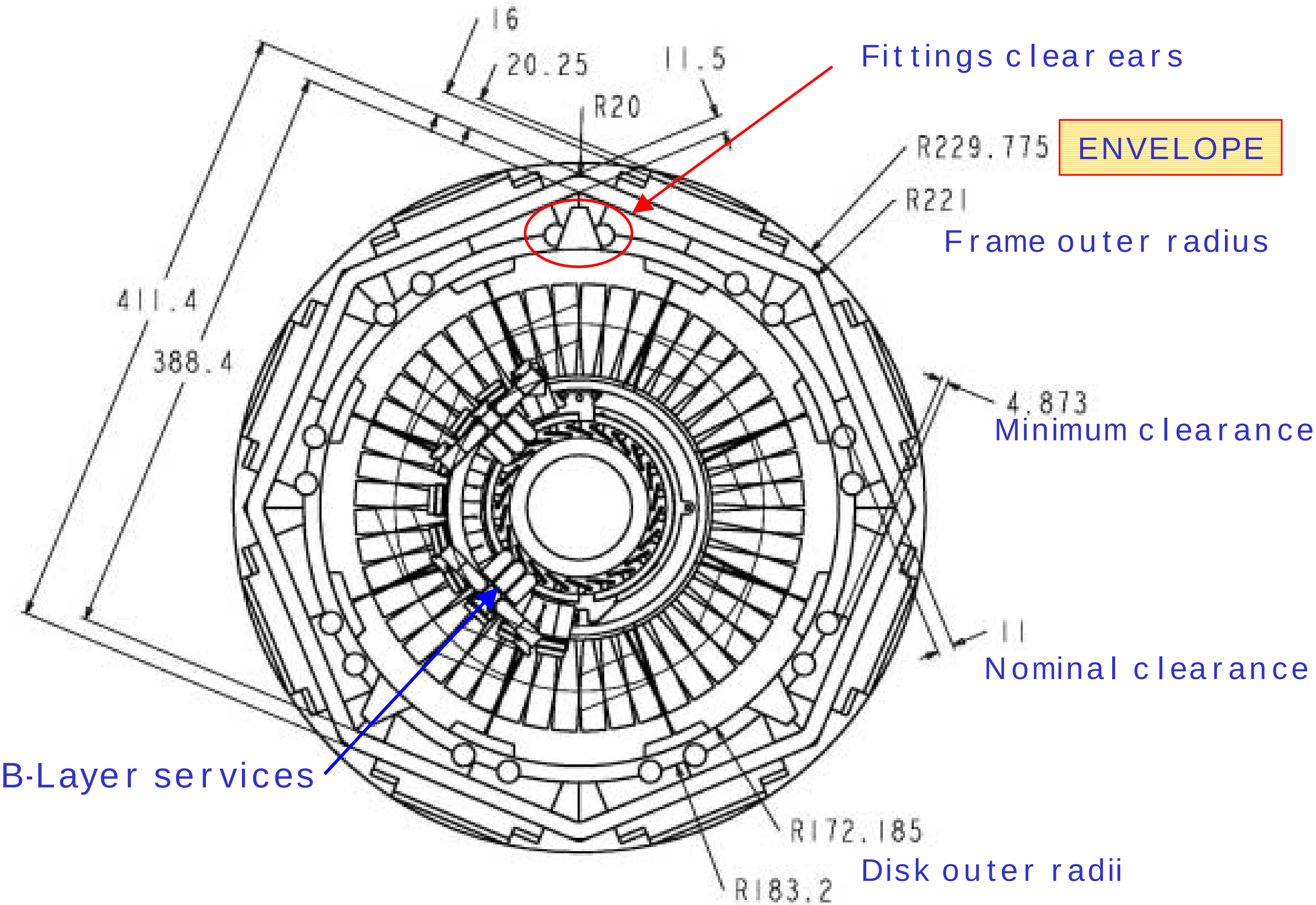


- **Disk 1 services must pass around a reversed disk**
- **Cooling tubes from disk 1 must snake around the ring and to smaller radius to accommodate the fitting**
- **Disk 1 is reversed to allow barrel services to be routed out of the frame--the position of disk one uses the gap defined in the baseline**
- **Goal has only 4 less staves than previous design, so most octants have same number of services**
- **Barrel Services define outer envelope**

Barrel Services are a major part of the envelope definition. These models use the same data for routing which has been verified with service mockups.

Pixel Detector

Detector End View

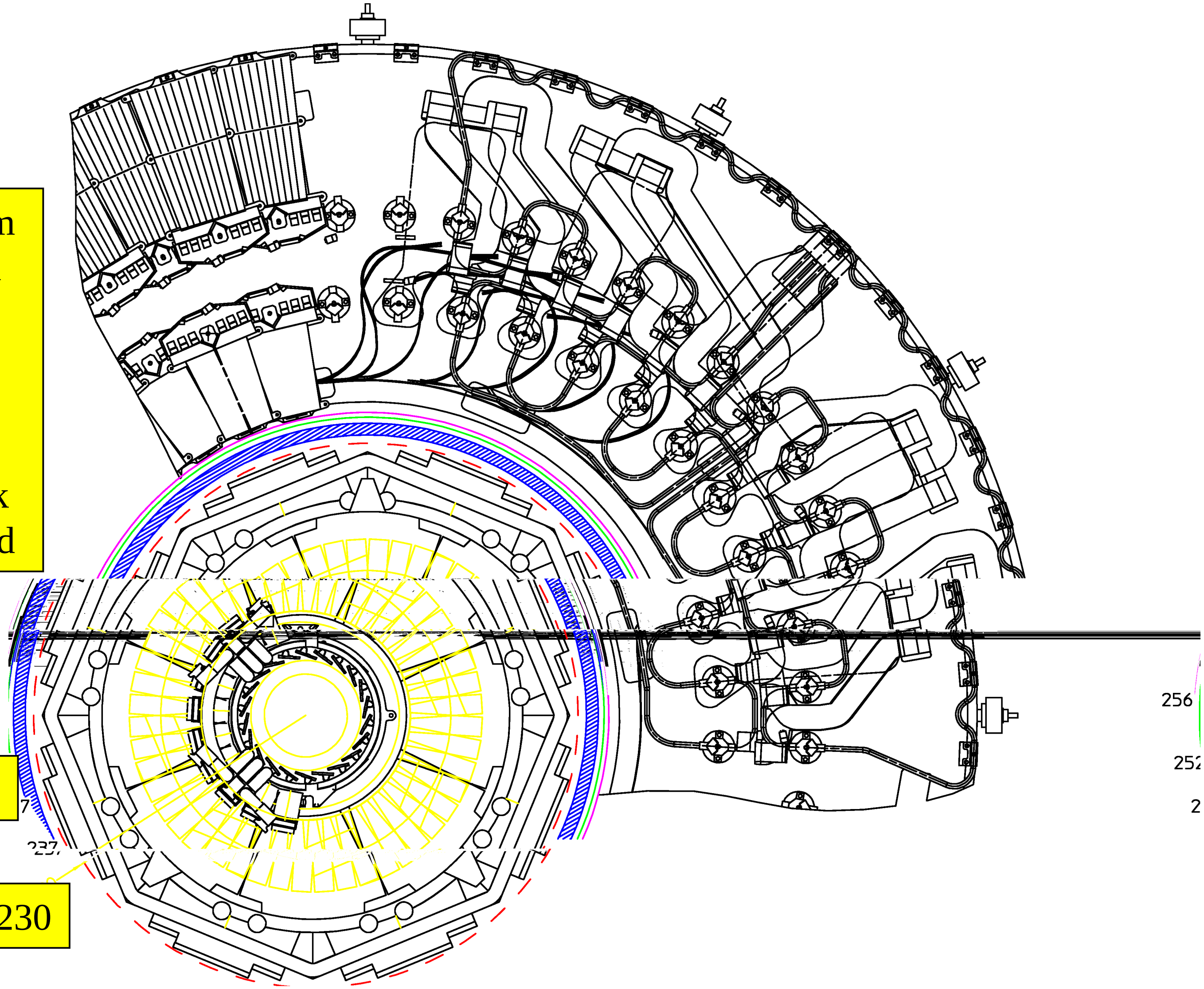


Pixel Detector

SCT-Pixel Envelope Clash

Assumption is that 15 mm needed between SCT and Pixel envelopes.

Current SCT and Pixel envelopes clash by about 8mm. Need detailed work to see if this can be solved

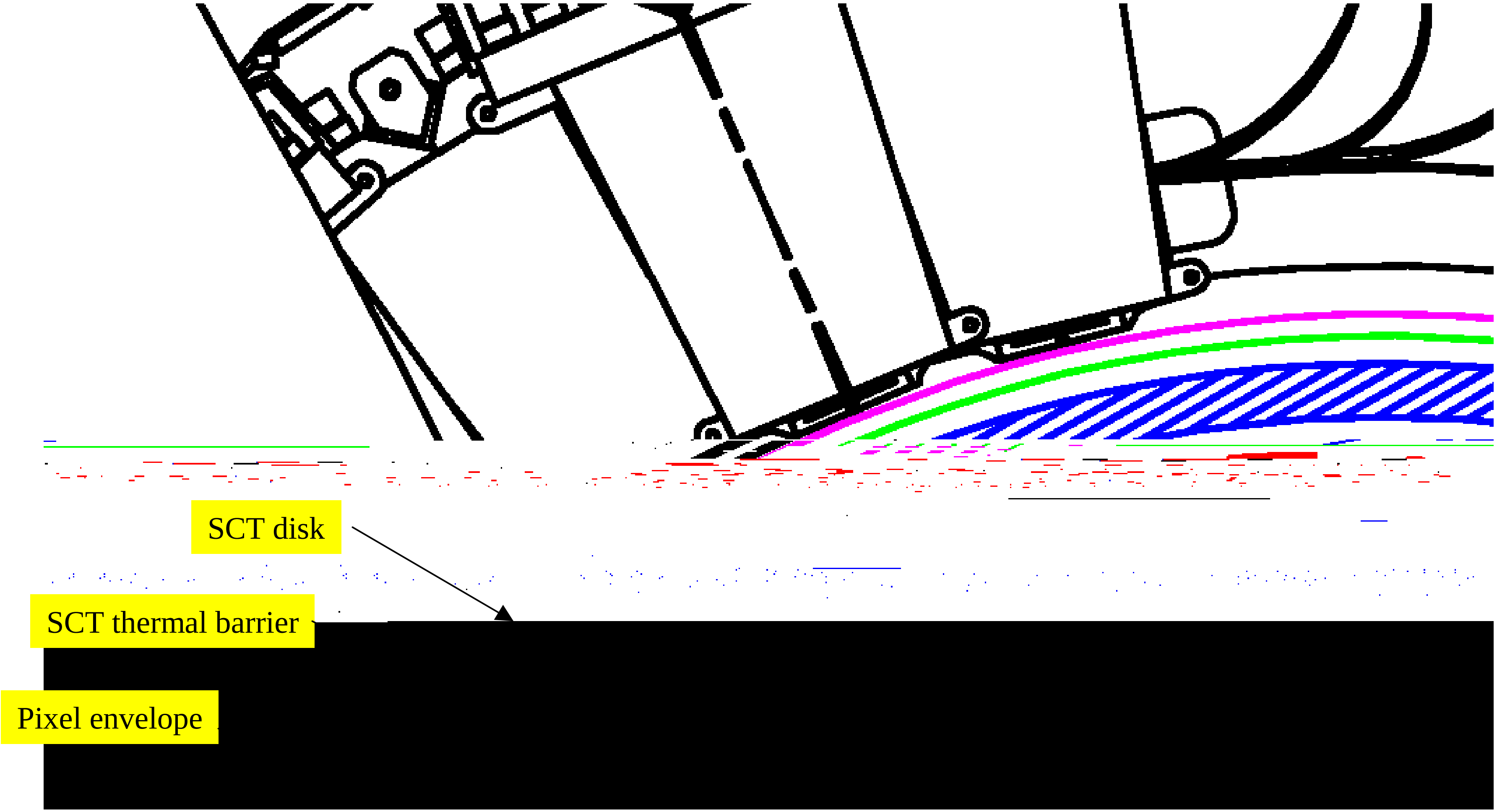


SCT envelope R=237

Pixel envelope R=230

Pixel Detector

SCT-Pixel Envelopes



Recent Developments in SCT Forward

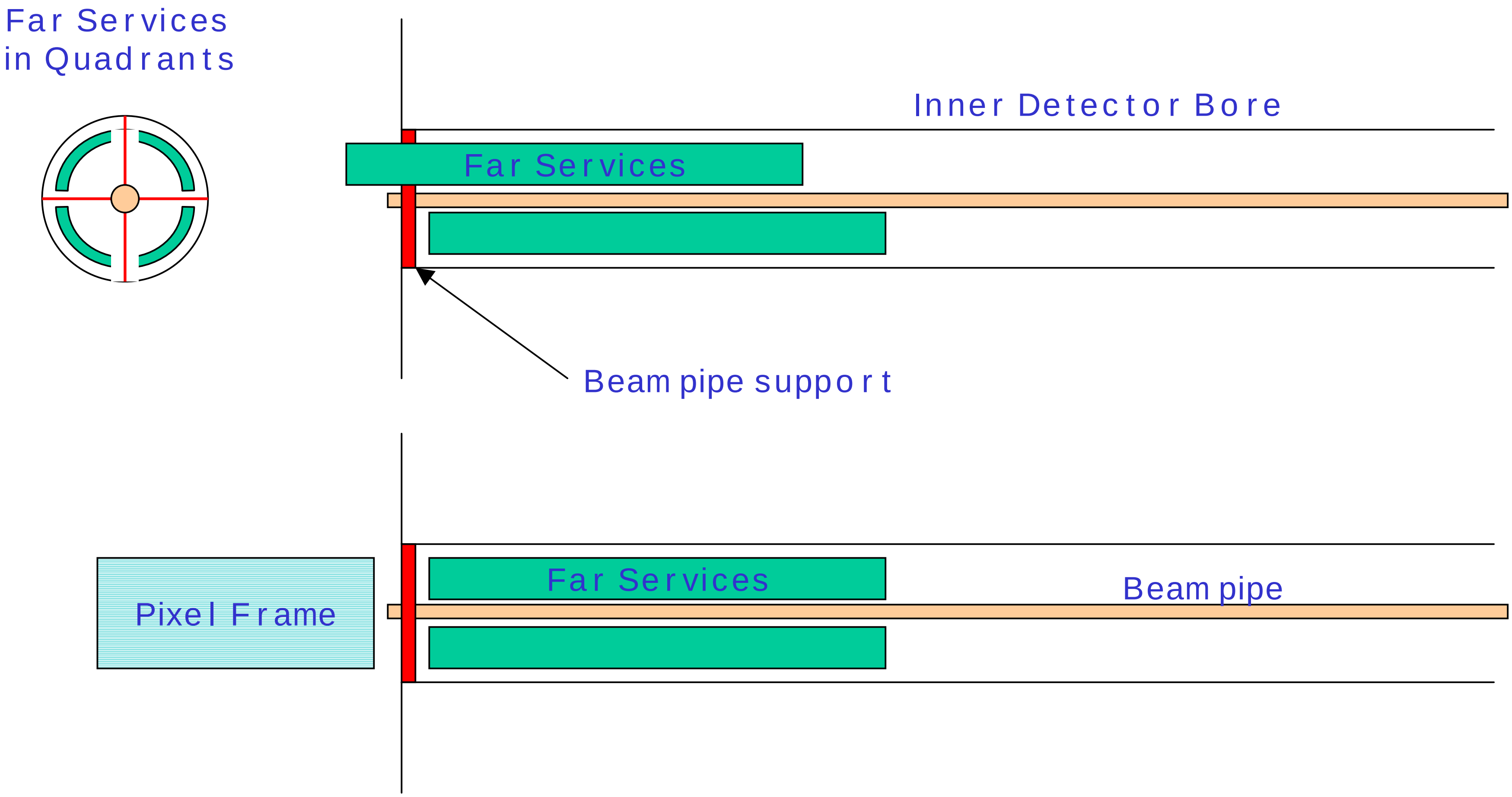
- SCT community has moved forward with idea to cut 11mm from their W12 wafer (innermost on disk)
- Meetings have been held to push along this effort, though no firm agreements are in place
- Major design effort to take place in November--starting next week--at RAL in conjunction with SCT engineers
- Major goal to leave RAL with detail designs of installation structures, thermal barriers, and Pixel Support.
- This is a major undertaking and relies on a firm mandate from the ID

Pixel Detector

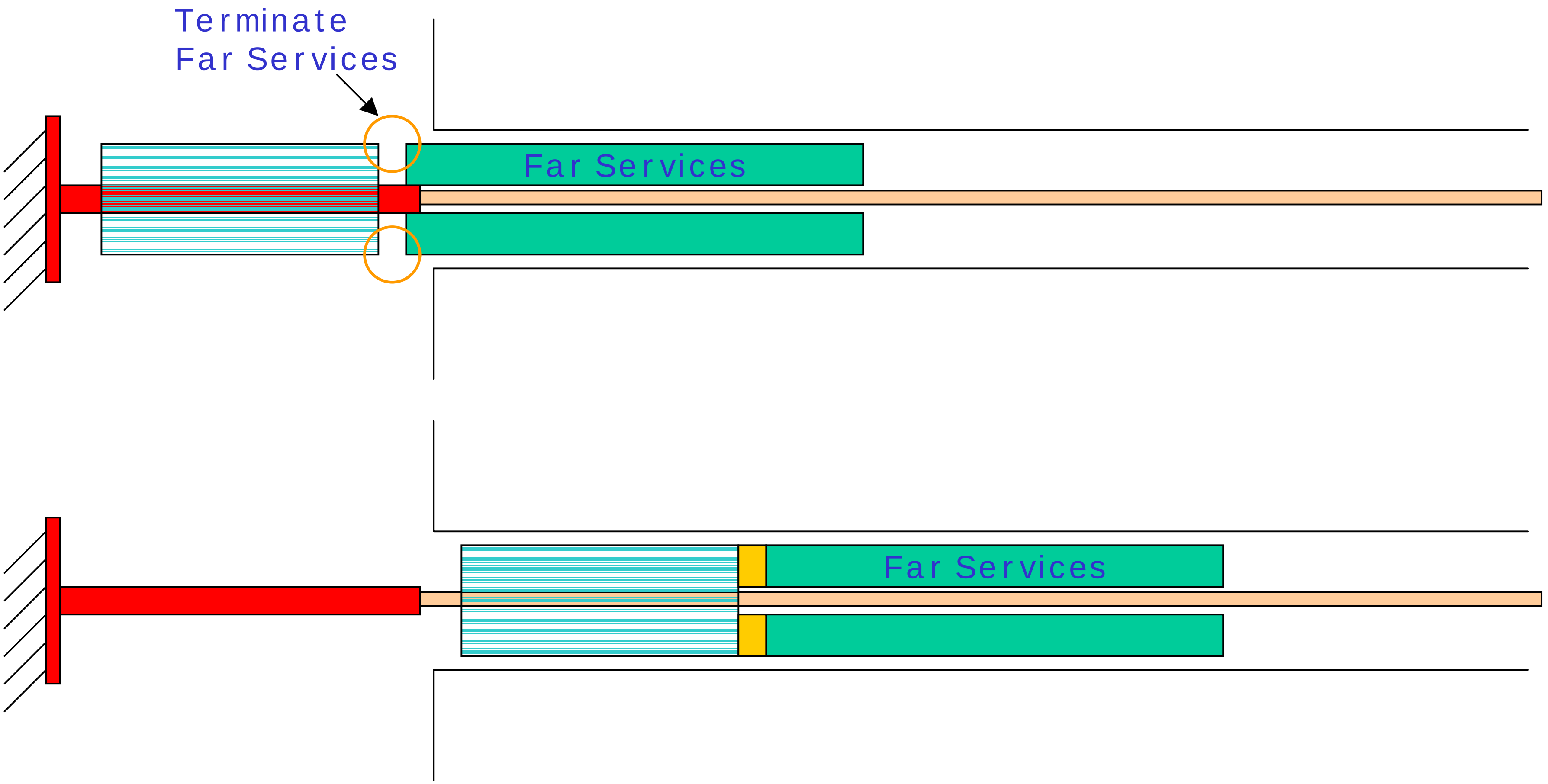
Insertion Sequence

- Argon Endcap is not present
- Far side Services are introduced in quarters
- Pixel detector is brought up to end of bore
- Beampipe auxiliary support is introduced through pixels and the support wires are removed
- Far side services are terminated to pixel detector and pixel frame is inserted into bore
- Vertical support wires are re attached
- Pixel detector is pushed 1.2m into bore of ID, and B-layer tooling is introduced as per current B-layer installation
- B-Layer is passed around supports and clam shelled around beampipe
- B-layer is inserted into Pixel detector on the baseline rail system
- The Pixel detector with B-layer is pulled back to the end face to allow near side termination of both Pixel and B-layer services
- Pixel detector and its services (near and far) with B-layer is pushed into position
- Services are terminated to the service runs to PP2

Far Services are inserted

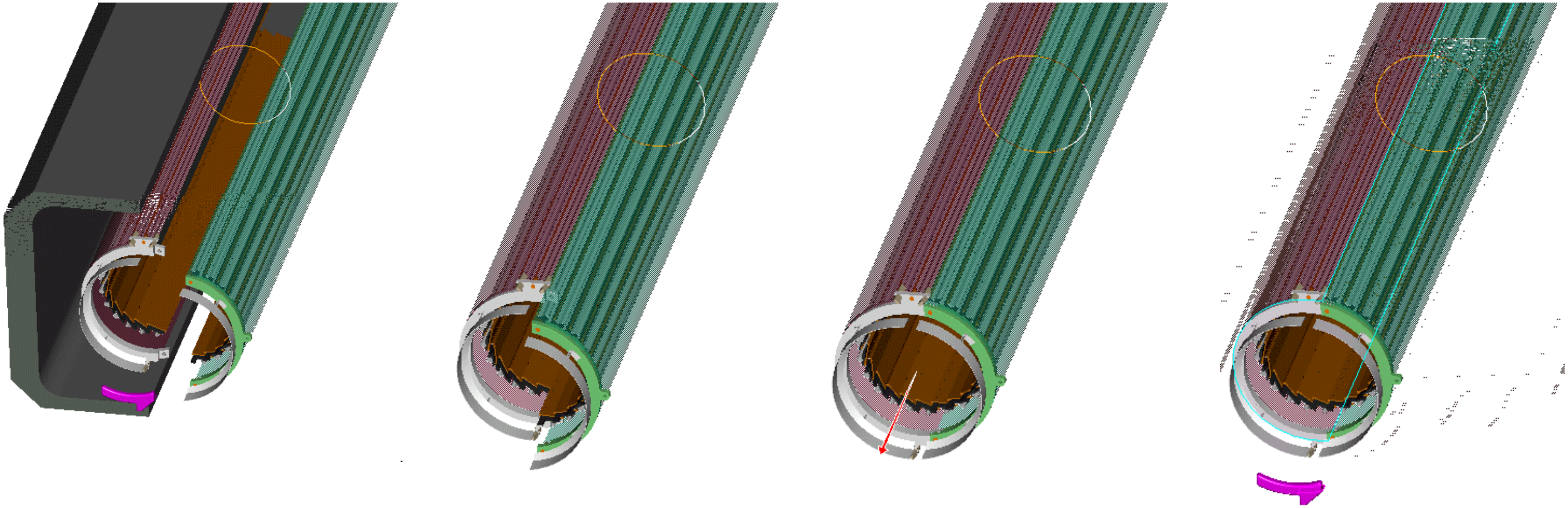


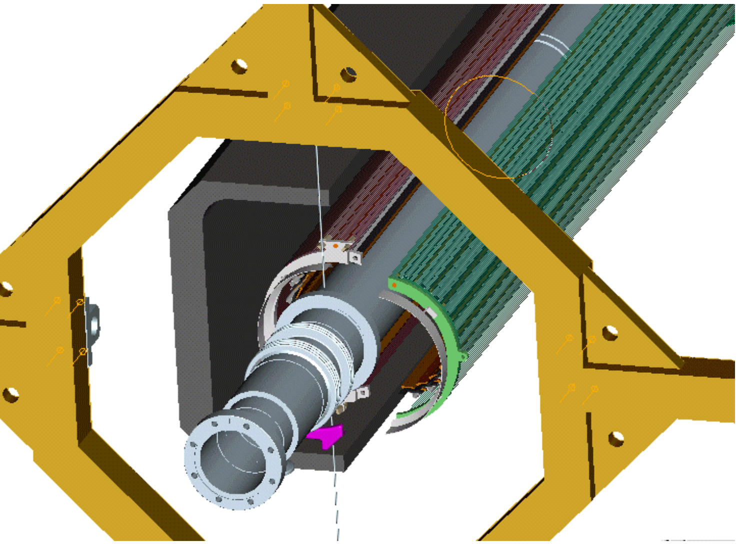
Far Services Terminated Pixels inserted



Pixel Detector

B-Layer Assembly Concept



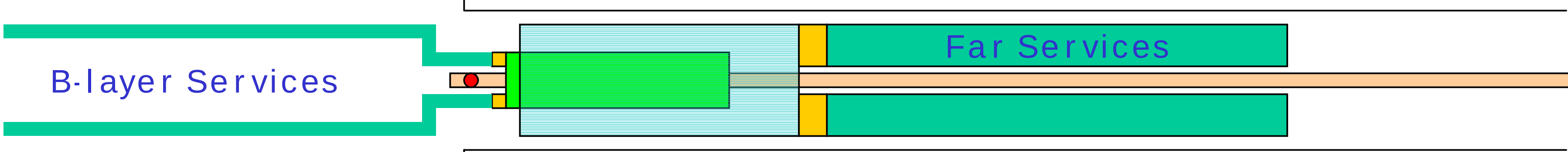


Halves are held together by longitudinal actuation

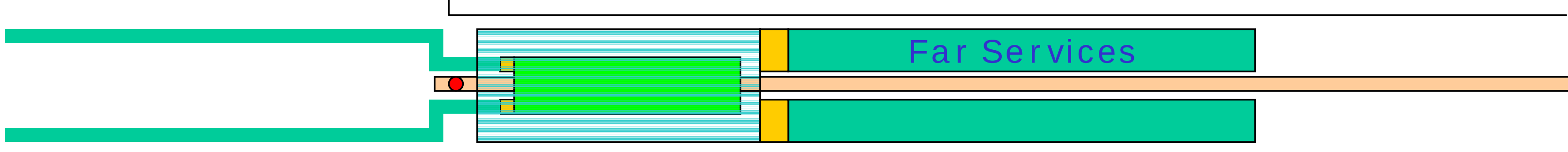
Preliminary design of tooling structures is consistent with space available now. Length of 1.2m required

B-Layer Installation Finish

To terminate the services to the B-layer, and the rest of the detector, the detector must be withdrawn to gain access



B-layer services are terminated first as they will be obscured by the rest of the pixel services

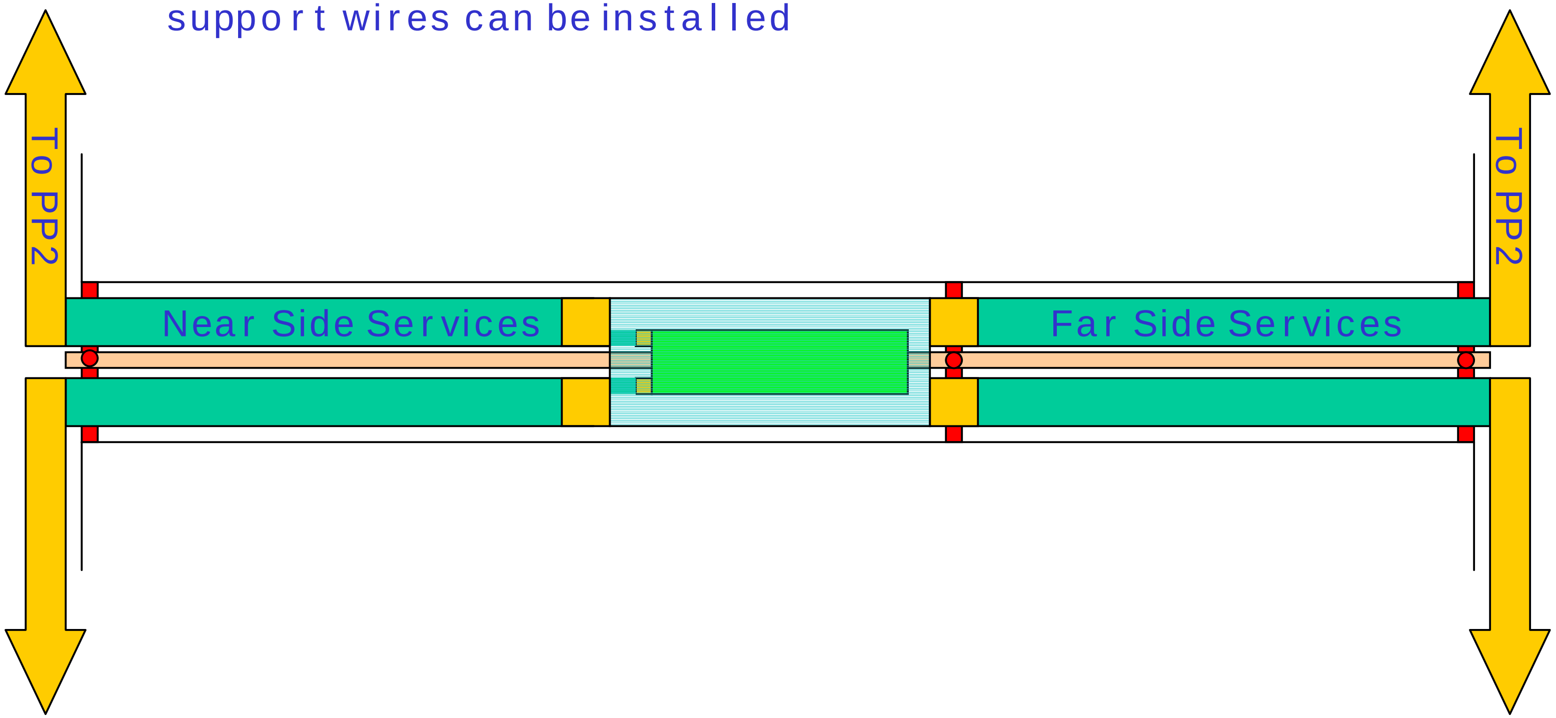


The B-Layer is then pushed into the frame into its final position. Depending on the length of the Pigtails on the B-layer, this step may be avoided

Pixel Detector

Pixels in installed position

After terminating the near side services the detector can be inserted fully. The services to PP2 can be terminated and if desired, on the near side, the horizontal beam pipe support wires can be installed



Pixel Detector

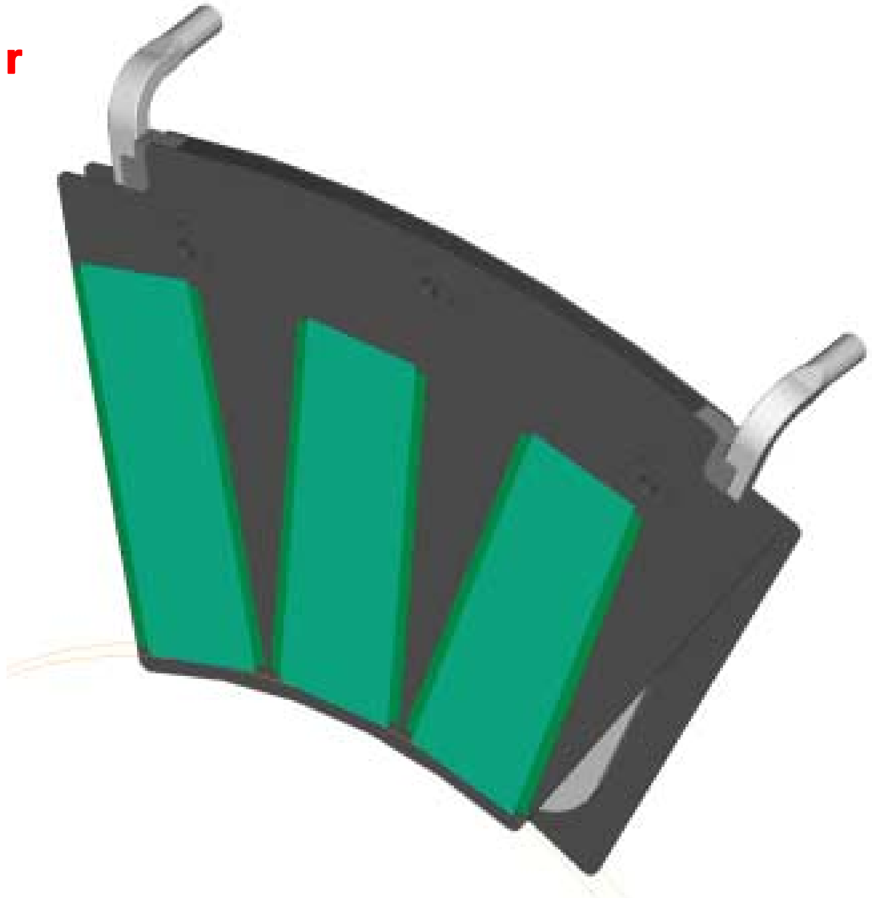
Mechanics and Final Assembly

- **1.1.1.1.3 Production**
  - 1.1.1.1.3.1 Disk Sectors
  - 1.1.1.1.3.2 Disk Support Rings
  - 1.1.1.1.3.3 Support Frame
  - 1.1.1.1.3.4 B-layer Support
  - 1.1.1.1.3.5 Thermal Barriers
  - 1.1.1.1.3.6 Services
    - 1.1.1.1.3.6.1 Mechanical Support
    - 1.1.1.1.3.6.2 Cables and Connections
    - 1.1.1.1.3.6.3 Coolant Pipes and Connector
    - 1.1.1.1.3.6.4 Patch Panel 0
  - 1.1.1.1.3.7 Disk Assembly
  - 1.1.1.1.3.8 Disk Region Final Assembly
  - 1.1.1.1.3.9 Test Equipment
  - 1.1.1.1.3.10 Installation

Pixel Detector

Disk Sectors 1.1.1.1.3.1

- Integrated support and cooling for disk modules.
- Each sector has 6 modules
- Number of sectors is 2x9+4x8=50.
- Fabrication of all sectors in baseline scope.
- Final Design Review - completed
- Production Readiness Review(of barrel staves and disk sectors) Feb. 2000, but could be earlier for sectors.
- Ready now to order production materials.
- Detailed production plan and manpower ready.
- All sectors made at LBL.



Pixel Detector

Baseline Sector Concept

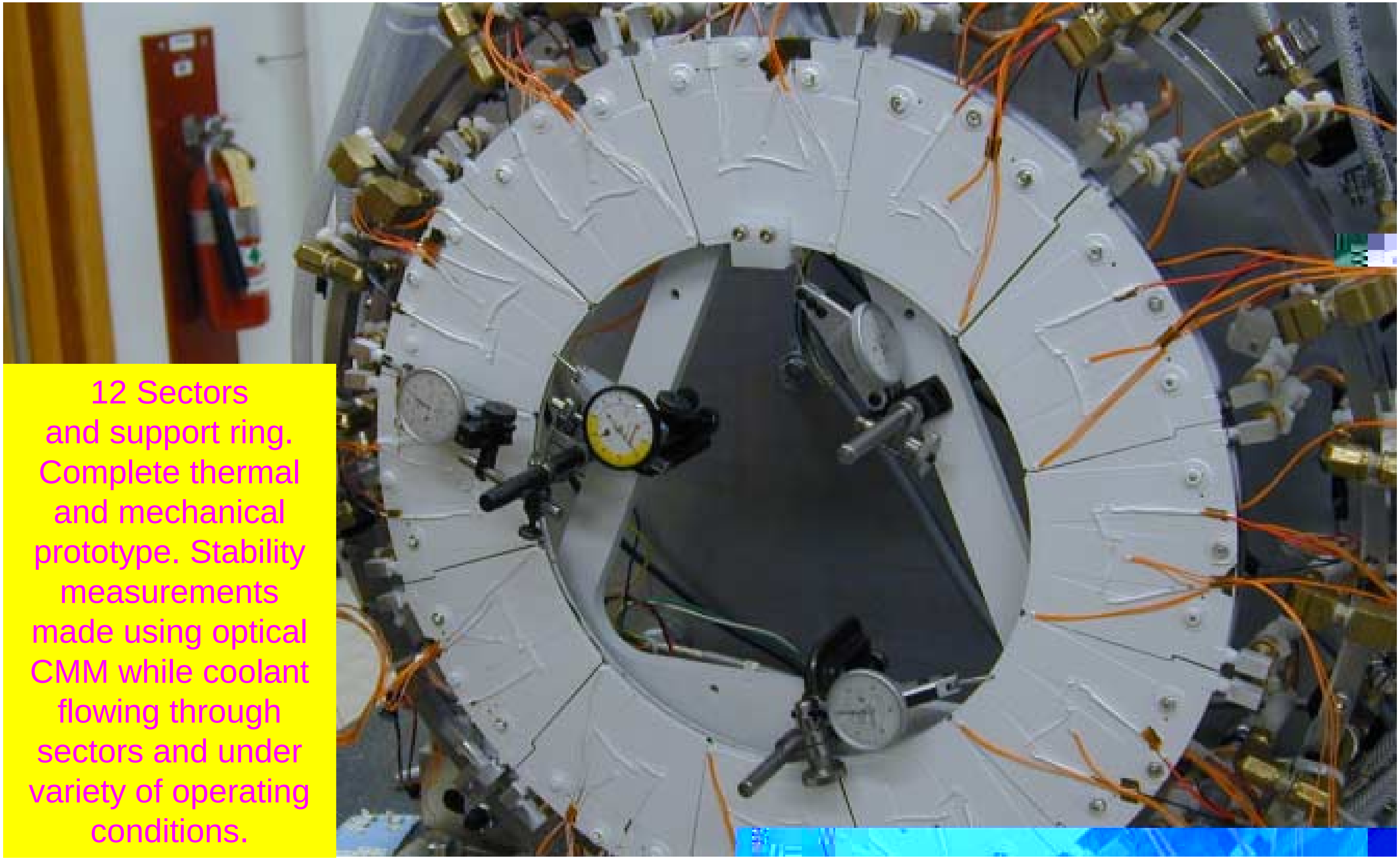
- Combined structural support with cooling.
- Carbon-carbon faceplates. Front and back faceplates offset in phi to provide full coverage(minimal gaps).
- Aluminum coolant tube between faceplates.
- Three precision support points to disk ring.
- Modules mounted on both sides.

Sector Design/Prototype Status

- **Twelve prototypes fabricated so far using baseline design concept. A few more will be fabricated before PRR to begin to iron out production details. Materials in hand.**
- **Additional >2x12 prototypes fabricated using similar but alternative design concepts(supported by DoE SBIR program). These have been used to construct and test(mechanically)two full prototype disks to evaluate disk support ring -> see photo next page and talk by W. Miller.**
- **Requirements document created for Final Design Review.**
- **Baseline sector concept meets all requirements(thermal, stability, irradiation to 50 Mrad,....)**
- **Only principal issue remaining to be addressed is fraction of stability budget(in Z) to apportion to sector, disk support ring, frame.**
- **Additional tests of sector stability(under temperature change) planned to allow better comparison with FEA to address this issue.**

Pixel Detector

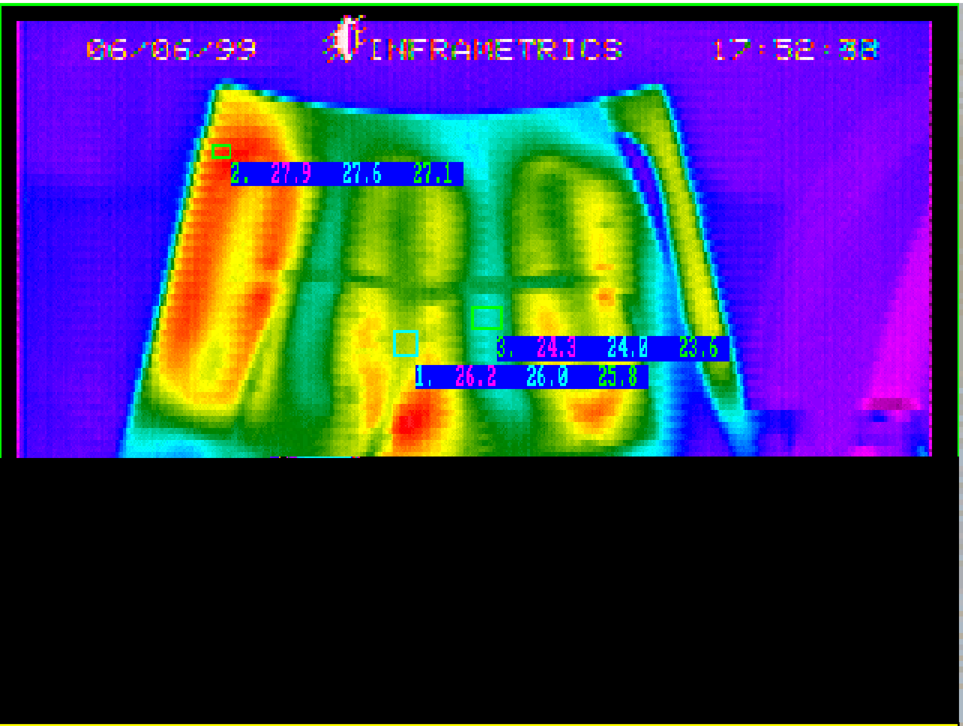
First Prototype Disk



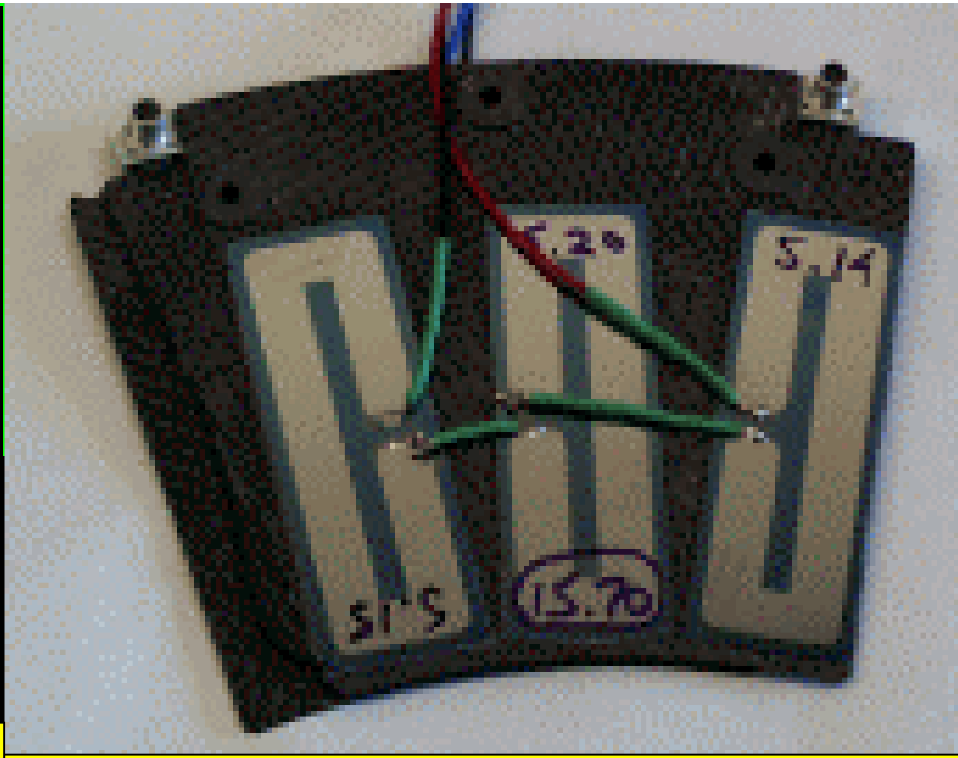
12 Sectors and support ring. Complete thermal and mechanical prototype. Stability measurements made using optical CMM while coolant flowing through sectors and under variety of operating conditions.

Pixel Detector

Thermal Measurements - Example



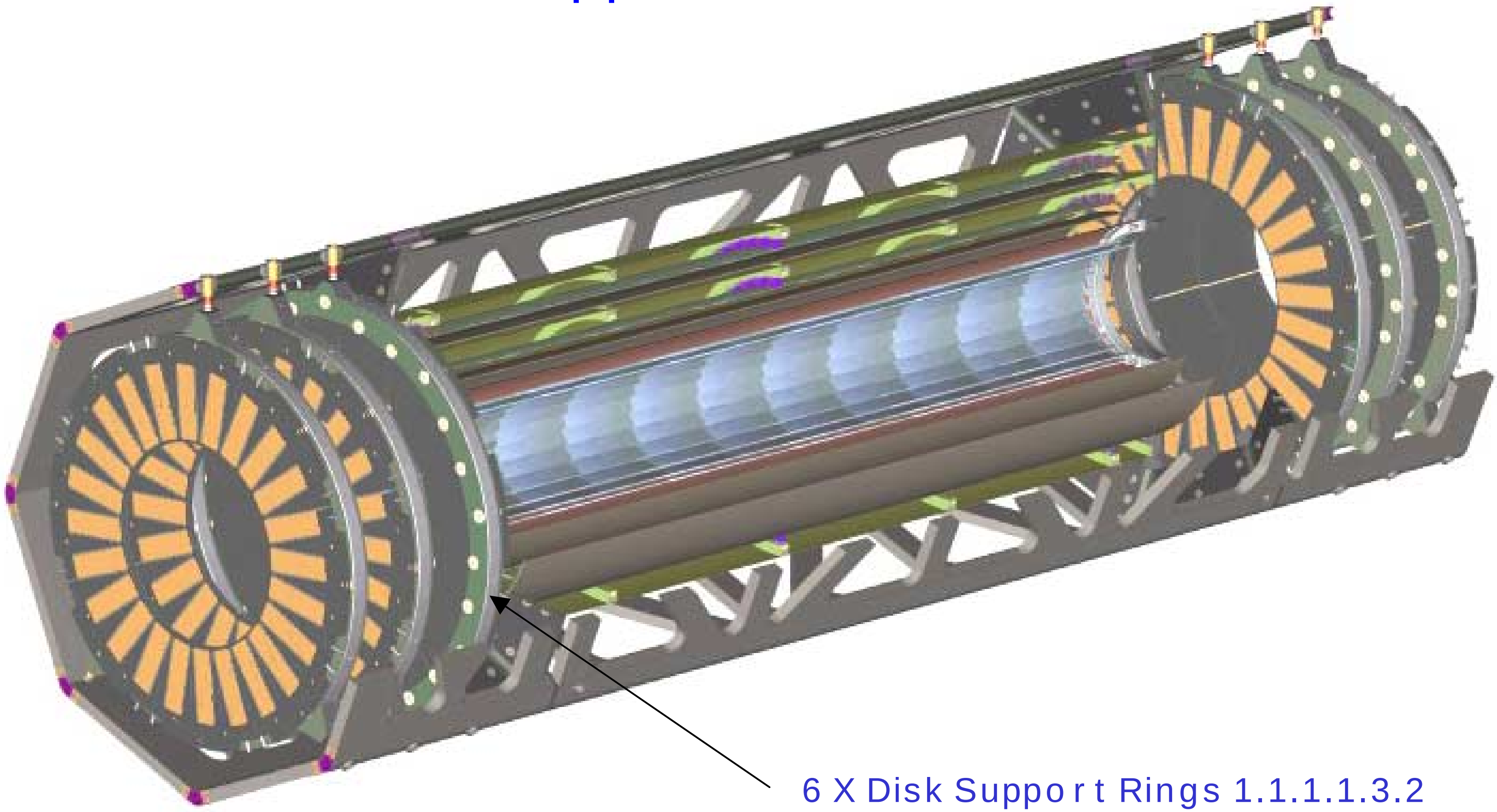
Infrared thermography has been used to assess thermal performance of sectors. This is a typical example of thermal performance using room temperature liquid cooling. Good correlation observed between ΔT seen in such tests and ΔT measured using baseline evaporative C_3F_8. IR thermography will be used in production QA.



Platinum on silicon heaters to simulate heat loads. These are attached using the current baseline thermal material CGL7018. RTDs are also mounted to measure temperature at points and compare with IR images.

Pixel Detector

Global Support Frame 1.1.1.1.3.3

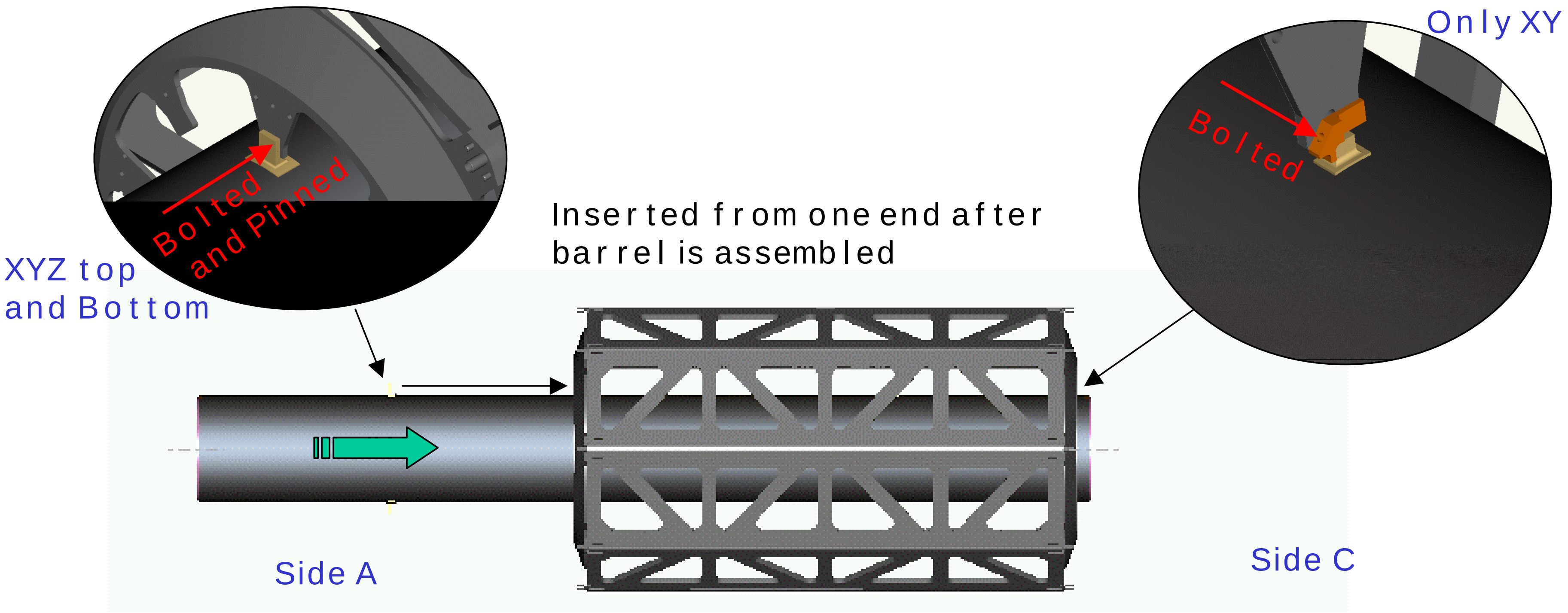


6 X Disk Support Rings 1.1.1.1.3.2

Following talk by W Miller will cover these two WBS items in detail

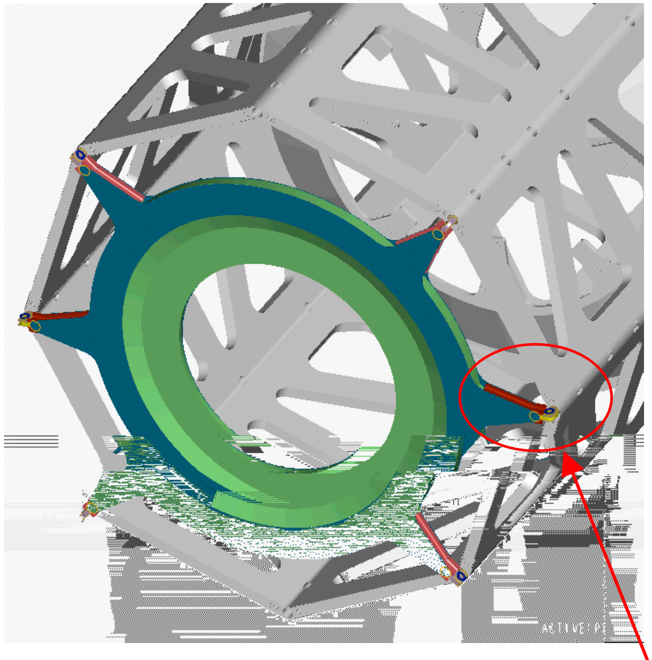
Pixel Detector

B-Layer Support 1.1.1.1.3.4

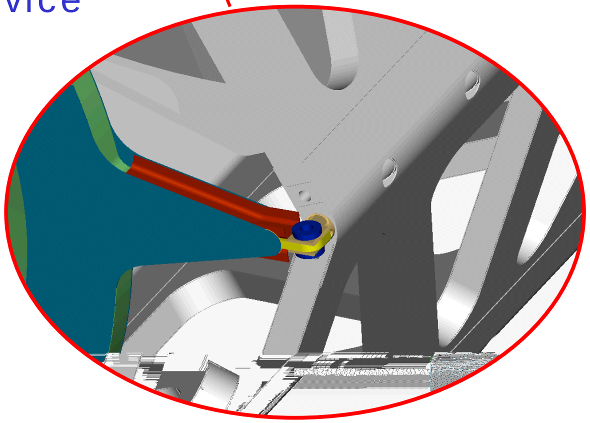


End Plate Stiffener 1.1.1.1.3.4

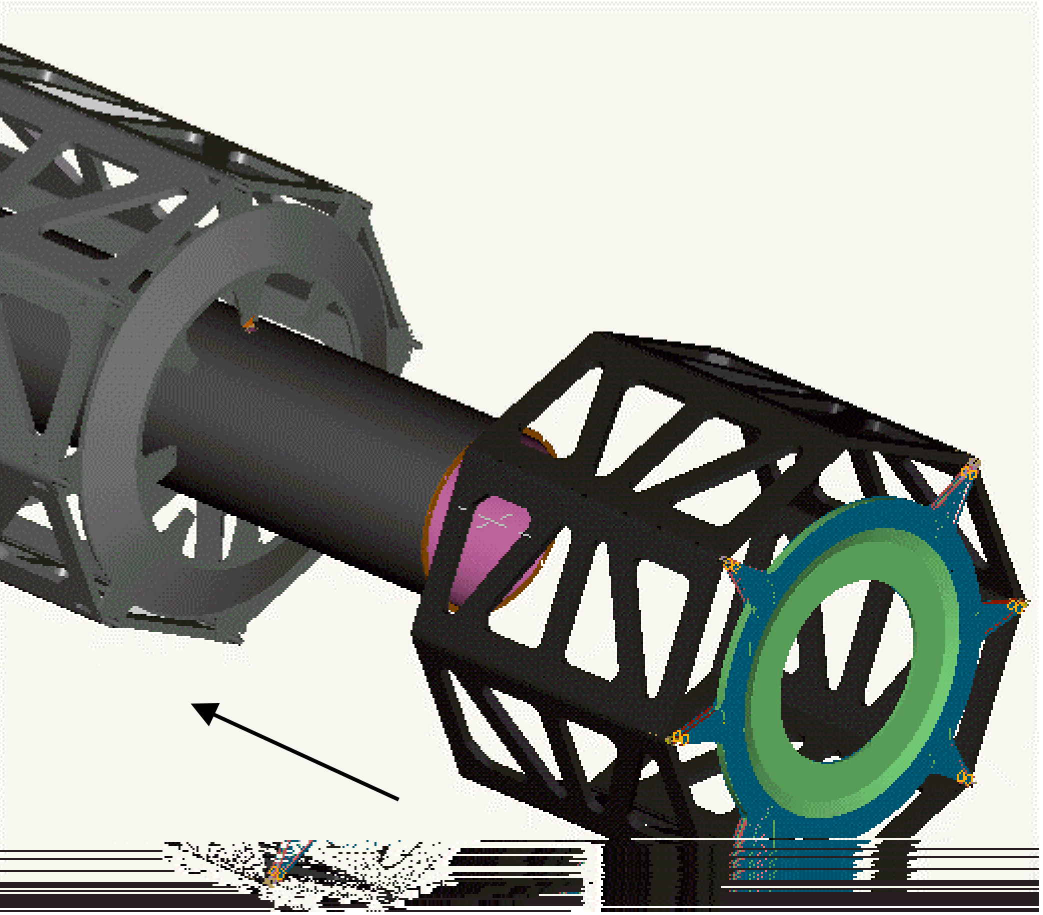
- **End Plate Stiffener increases the radial stiffness of the Octagonal Frame**
  - Inserts in Global Support Frame and End Plate are Pinned together--helps to hold End Frame ‘round’
- **B-Layer support flange attaches flexibly to End-Plate Stiffener**
  - (not shown)



(Shown without service integration details)



Assembly of Support Frame

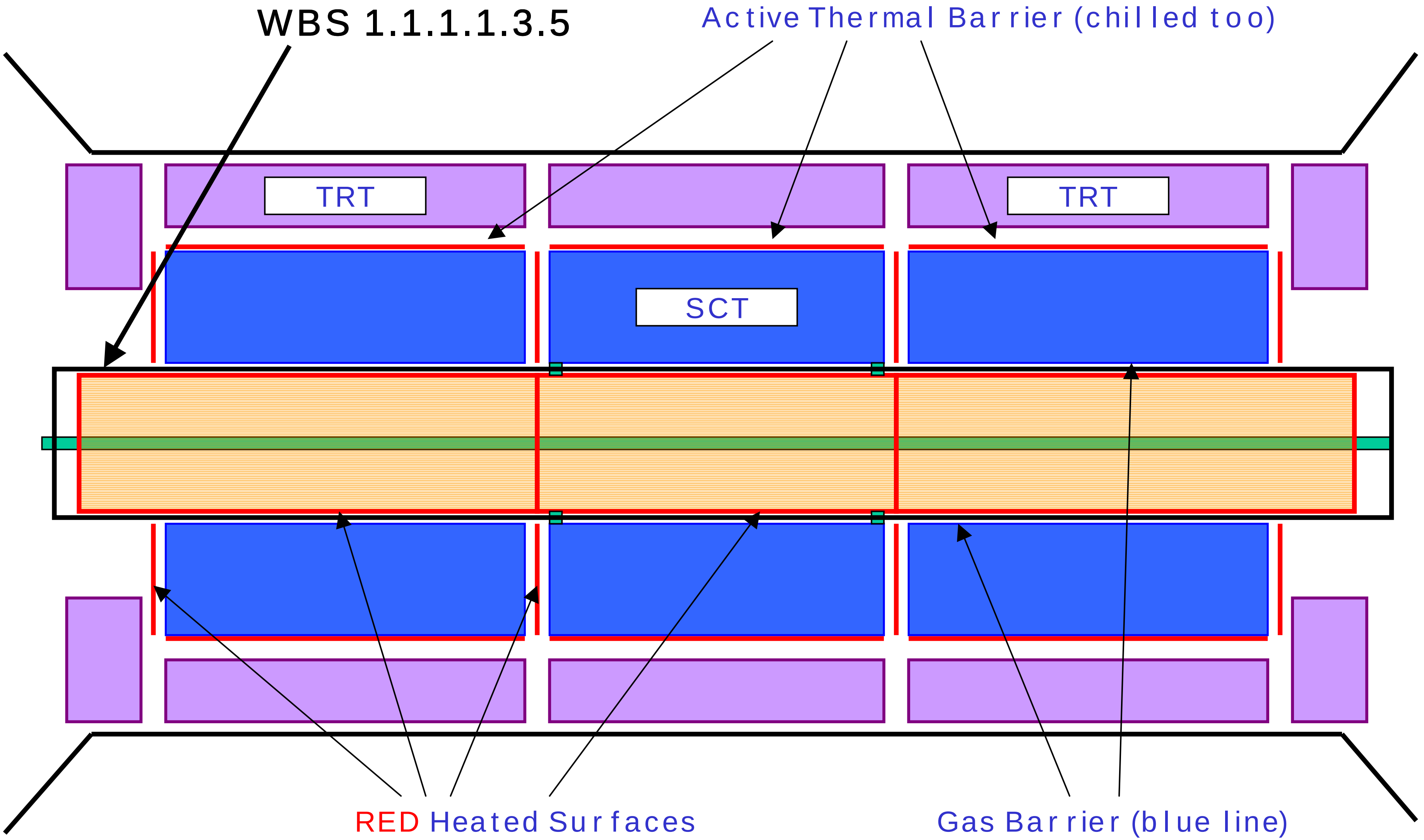


- **B-Layer support is integrated with Barrel Region**
- **Takes all location from Support fingers**
- **End Frame is brought up and bolted into place**
- **Services (not shown) need support during all operations**

End Plate stiffener is a useful part of end frame as it both supports the services as well as helps to make the end frame self supporting for installation

Pixel Detector

Thermal Barriers 1.1.1.1.3.5

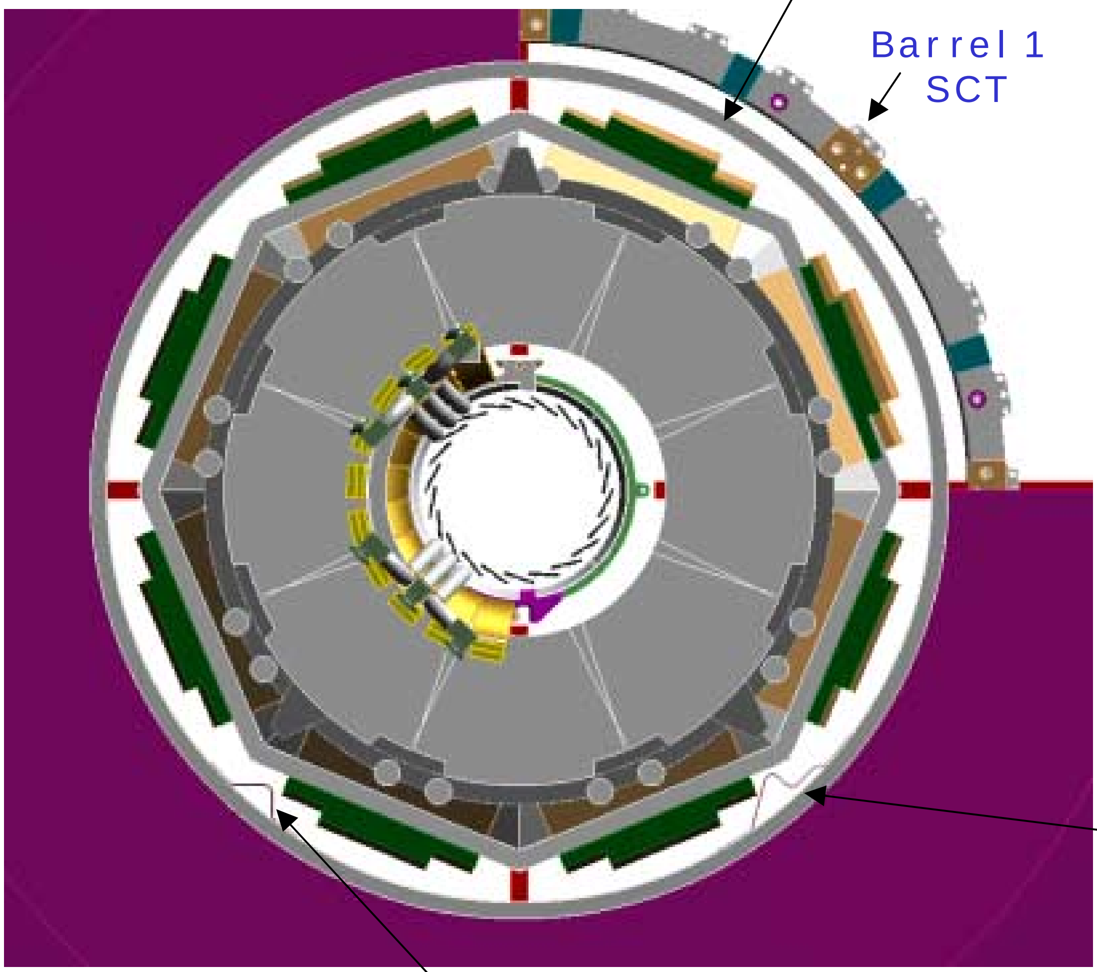


Integrated Tube Supported from Barrel

- The thermal barrier will have integrated rails and may provide the warm side of an active thermal barrier
- The SCT forwards and barrel, will provide the cold side of the barriers which is also a dry gas container
- Currently, the entire production, structural prototype and bulk of the design is 100% management contingency
- 6mos of intense design, and some monies for mock-up are in the base project
- It is assumed that this is the way to go, but buying in must only follow better understanding of design and cost--and management decision

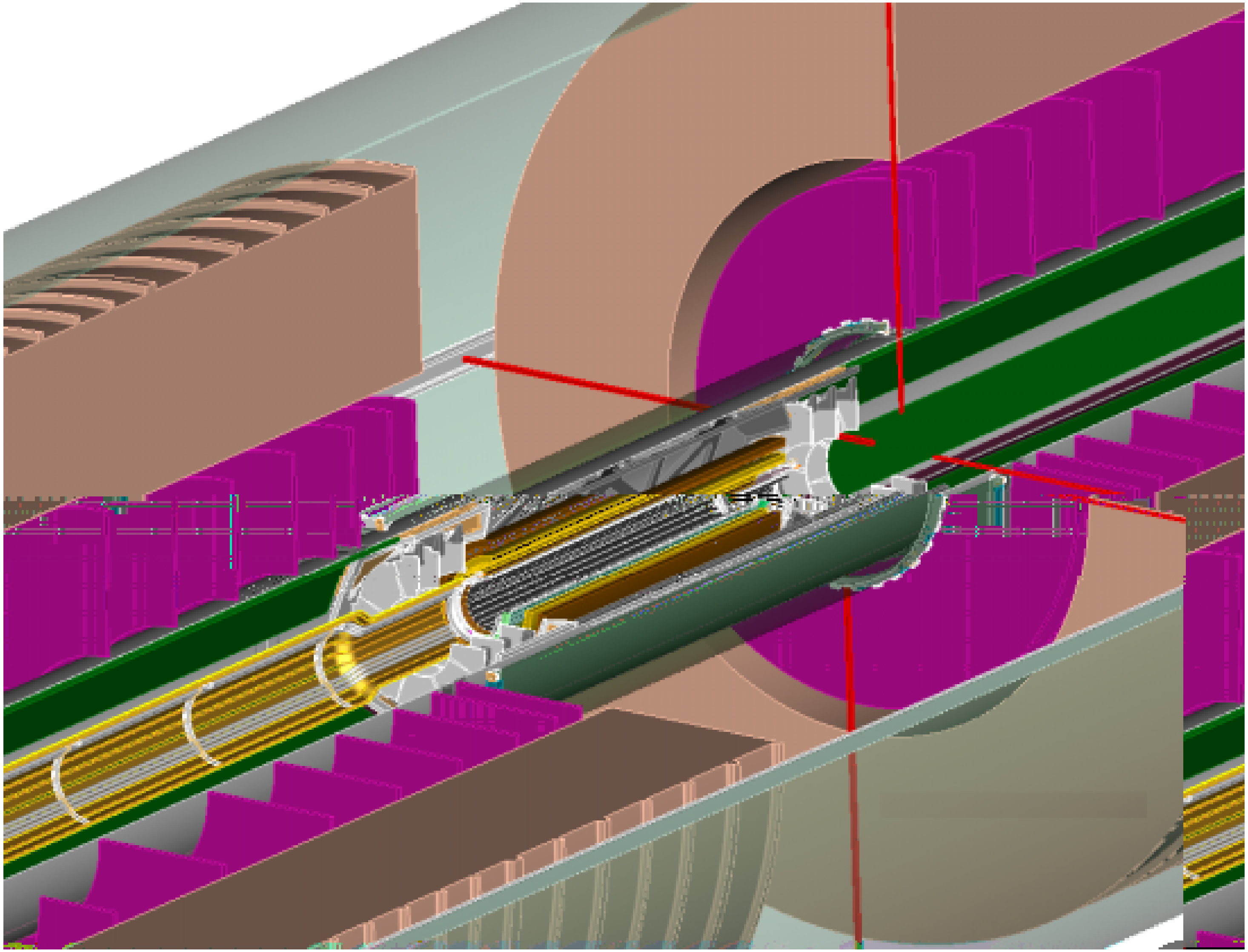
Pixel Detector

Thermal Barrier as installation Rail



- **Using a V-Flat rail configuration is pseudo-kinematic**
- **Will investigate ways to transfer loads to "accurate" fixation points at home location of detector**
- **Integration of purposes (thermal and installation) is crucial for space and material constraints**

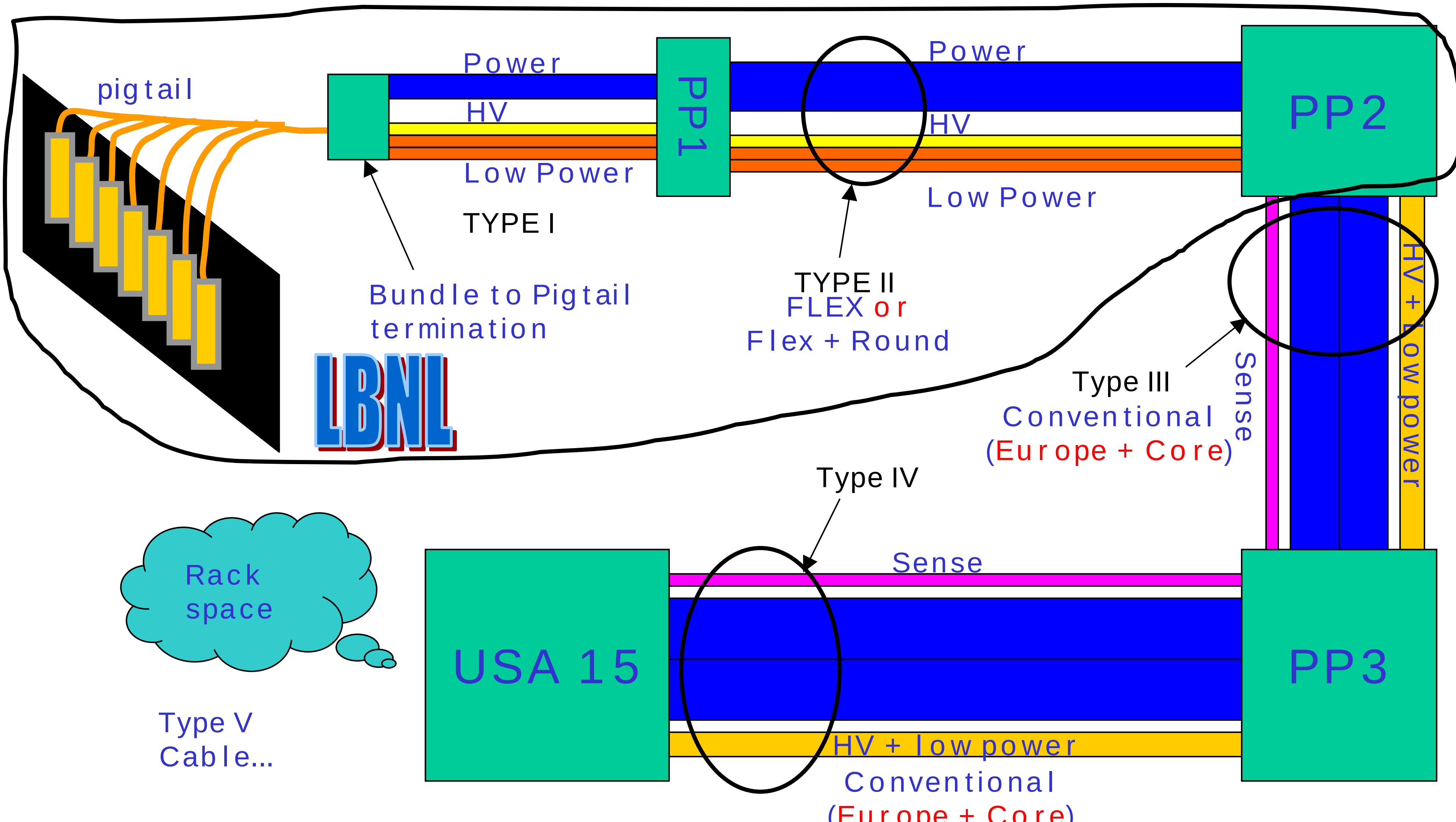
ID with Installed Pixels and Thermal barrier



Beampipe not shown for clarity

Pixel Detector

Cable Bundles Schematic 1.1.1.1.3.6.2

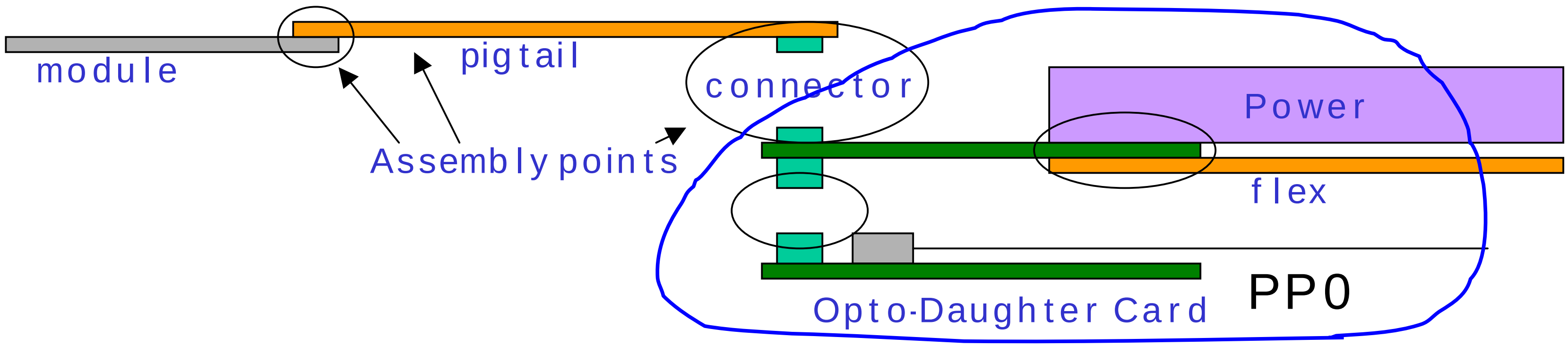


Pixel Detector

Definition of Bundles

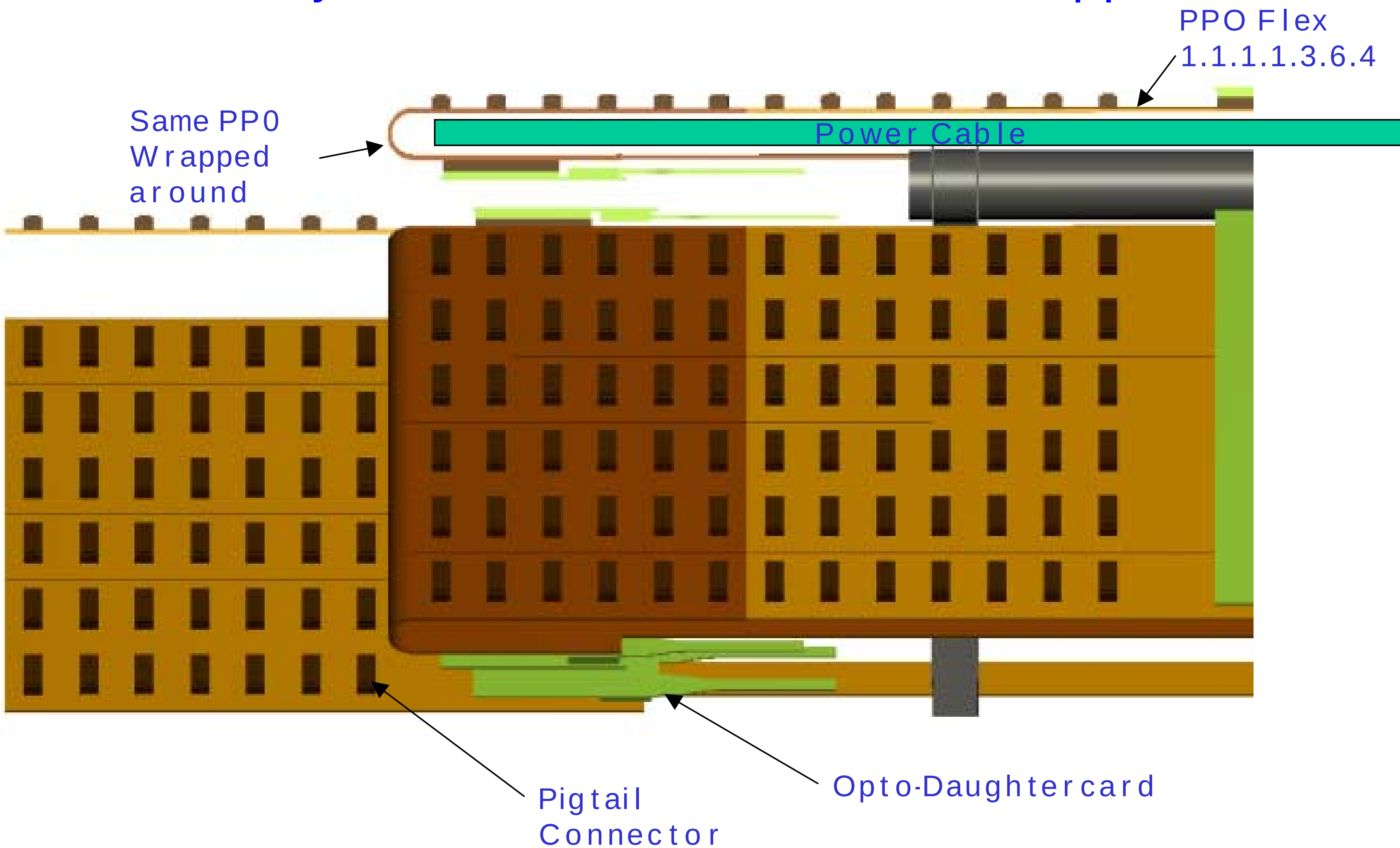
- **A bundle powers 1/2 sector or 1/2 stave (6 or 7 modules)**
- **Cables within bundle can be divided into two categories--High and low power**
- **These can use different technologies to meet requirements**
- **Definitions of components**
  - **Power** Cables for 6/7 modules
    - **Vdd, Vdda, Vcc, Vvdc****
    - Round wire with conductor thickness and pitch sized for current
    - Flex--Types I and II are each different art
    - Twisted pair option jumps in conductor size at PP1
    - **only one Vvdc per bundle not one per module
  - **Control** Cables for 6/7 modules
    - **NTC, Iset0, Reset, Vpin**
    - Minimum technological thickness and pitch conductor flex cable
  - **High Voltage** Cables for 6/7 modules
    - **Vdet**
    - nominally same flex technology as control, but meets HV requirements
    - Integrated into PP0 flex for type I
- **One PP0 serves One Bundle**

Pigtail to Cable Connection 1.1.1.1.3.6.4



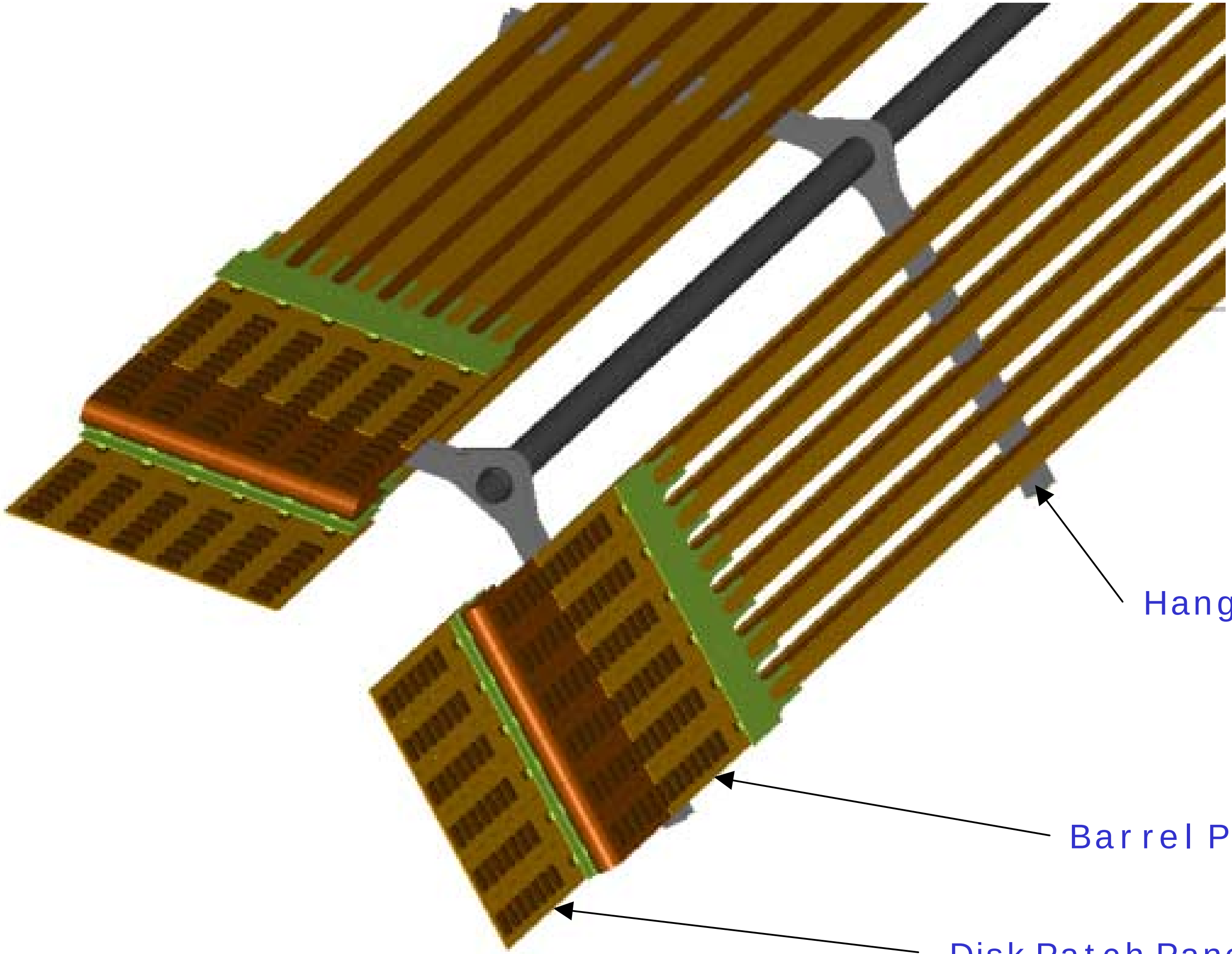
- **PP0 moves all the way to the end of the pixel frame**
  - allows fibers to be integrated with services mechanical support
  - Pigtail entirely electrical structure
- **Concerns**
  - Pigtail doubles in length for barrel
  - Opto-package even further away
- **All final interfaces now electrical not combined Opto-electrical**
- **Re-evaluation of voltage drop budget necessary**
- **Concerted test program started to measure performance of Opto-packages at this distance**

PP0 array on Service Mechanical Support



Pixel Detector

Services Mechanical Support 1.1.1.1.3.6.1

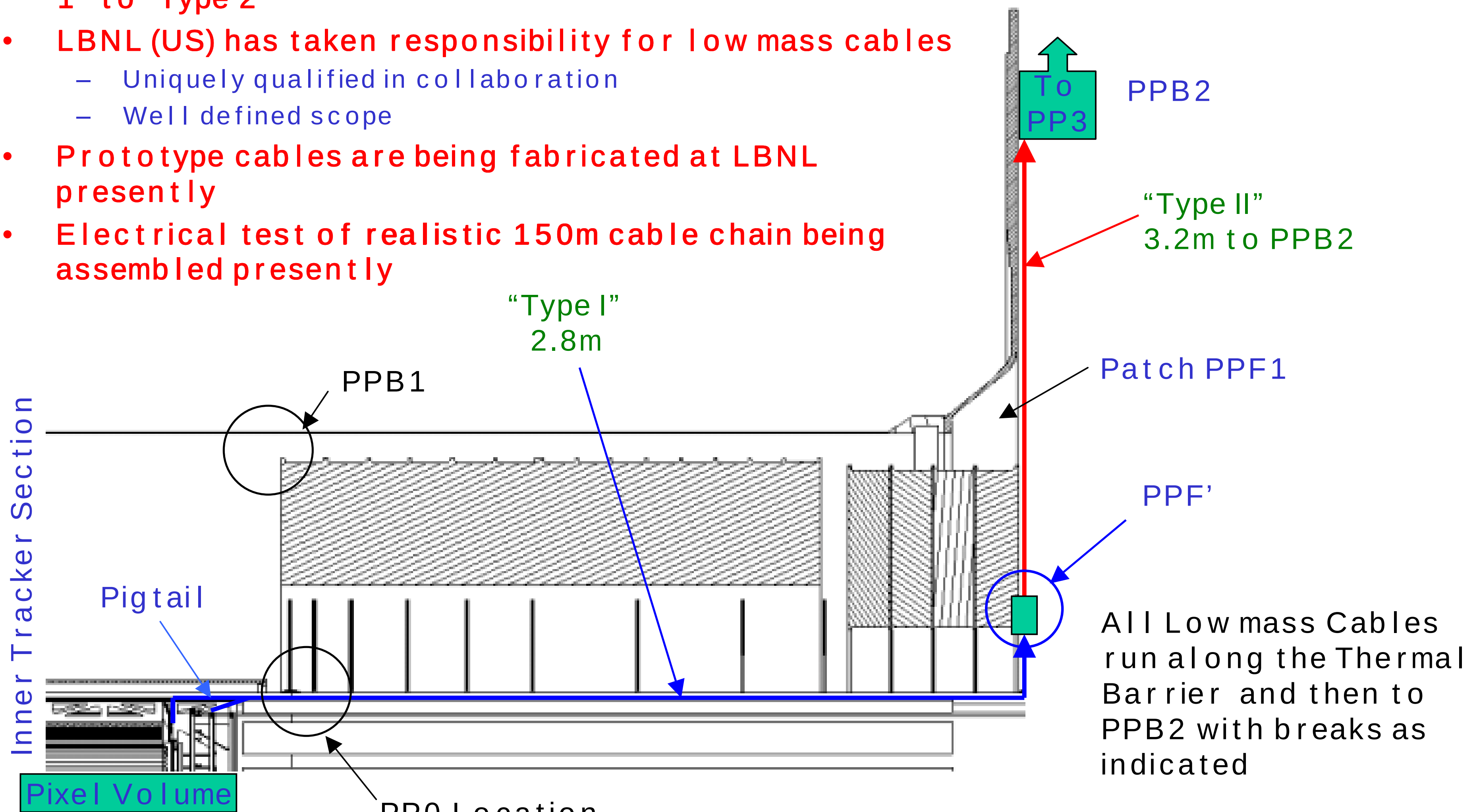


Structure necessary to support services during installation scheme

Pixel Detector

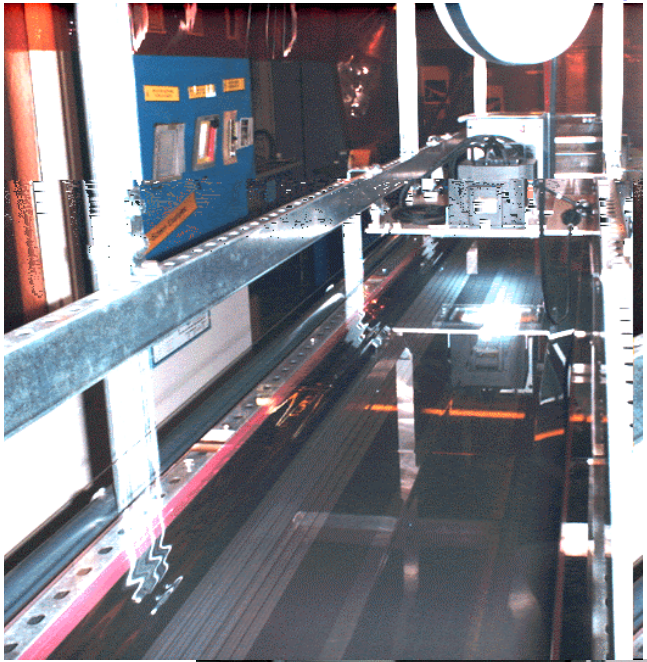
Cable Types I & II (low mass cables)

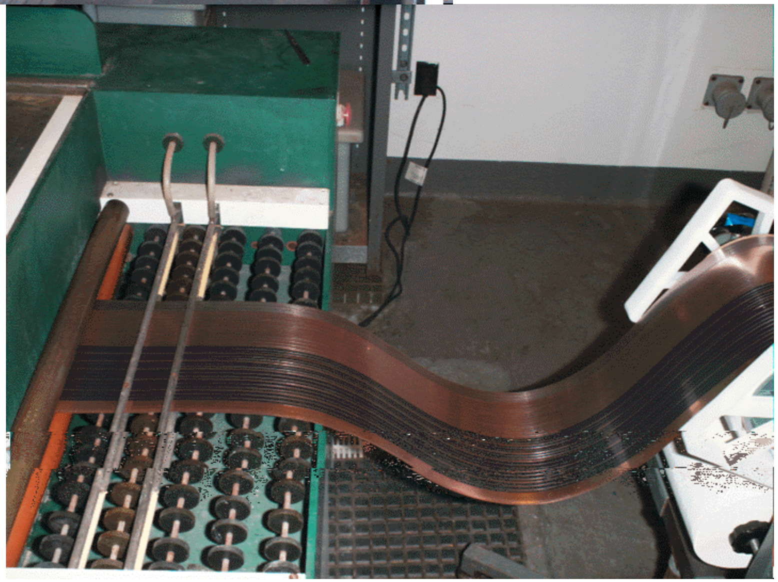
- Power cables change size at PPB1 and PPF1 from “Type 1” to “Type 2”
- LBNL (US) has taken responsibility for low mass cables
  - Uniquely qualified in collaboration
  - Well defined scope
- Prototype cables are being fabricated at LBNL presently
- Electrical test of realistic 150m cable chain being assembled presently



Pixel Detector

Prototype Electrical Cables

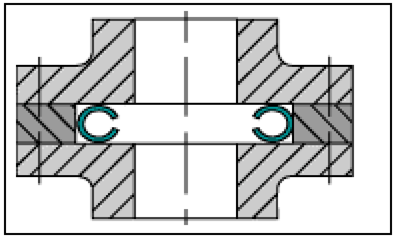




- **Flex Cables being produced at LBNL**
- **Wire partly purchased**
- **Artwork has All cable types in low mass bundles**
  - Types I&II power, Mintrace, HV
- **Prototype effort started with copper**
  - Copper remnants from STAR OFC
  - Shop really geared for Copper
  - quickly prove out staging and production aspects

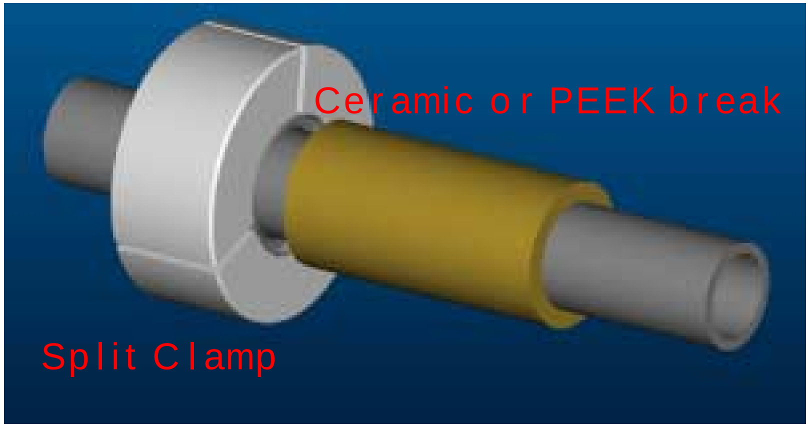
Cooling Connections 1.1.1.1.3.6.3

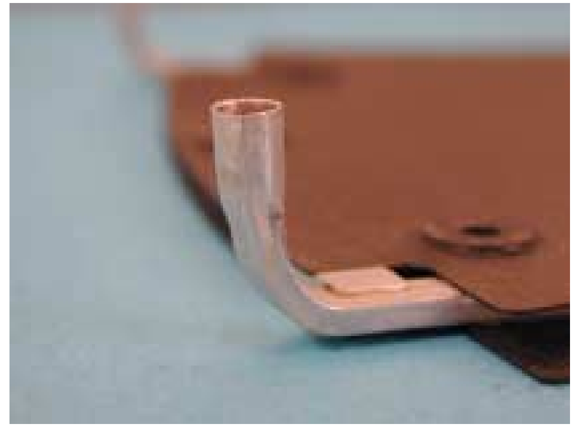
- **Custom Aluminum Fittings**
  - 6061 or 6063 machined fittings
    - low mass
    - shaped for either braze or adhesive joint geometry (see subsequent slide)
  - Standard O-ring type groove
  - Custom split clamp
    - low profile and low mass
    - prevents unwanted torque
- **Standard Seals**
  - UHMWPE face seal with SS internal spring - Variseal Brand (www.variseal.com)
  - O-ring compatible groove
  - Also consistent with all-metal Wills C-ring type gasket
- **Permanent Connection**
  - tube to tube and tube to fitting
    - Brazing
    - Adhesive



Wills C Ring

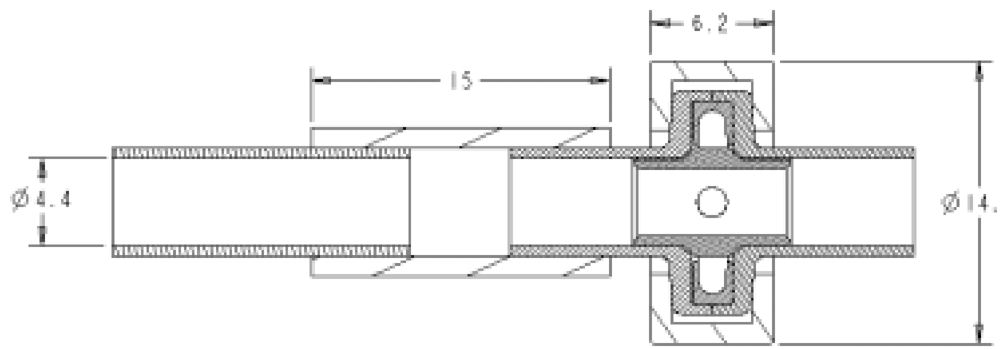
Proposed Real Sector Fittings





Proposed swage on end of sector tubing

Proposed U-tube design with electrical break



Pixel Detector

Permanent Connections

- **Brazing**
  - 6063 Aluminum fittings at demountable breaks and sector terminations
    - higher melting point than 6061
  - 3003 Aluminum sector tubing and exhaust tubing
  - Capillary material unknown
  - Two braze techniques have been tried
    - vacuum furnace brazing
    - hand torch brazing
  - Metallized alumina pieces used to create electrical breaks
- **Adhesive Bonding**
  - 6061 Aluminum fittings at Demountable breaks and sector terminations
  - 3003 Aluminum sector tubing and exhaust tubing
  - Capillary material unknown
  - Hysol 9396 adhesive has been used - 9394 may also be desirable
  - Electrical breaks created by PEEK inserts

Brazing Results

- **Torch results are good for certain geometries**
  - Melting of the parts was not a problem
  - Wetting was not very substantial - but filleting could be easily achieved
  - Surface quality at overheated areas was poor - need to simply use care in application of torch

Failed Paste Furnace Braze

Successful Paste Furnace Braze

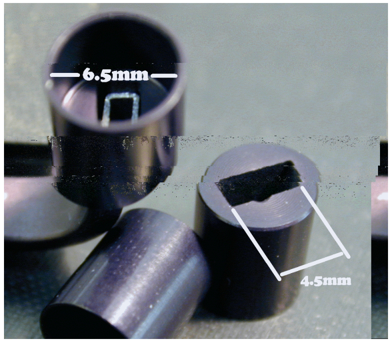
Porous but leak tight paste braze

Successful wire fillet braze

- **Furnace brazing turned out difficult to control**
  - Temperatures could not be kept even along the part as well as desired (about 10 degrees variation)
  - Wetting was not very substantial
  - Surface quality on components cycled in furnace were variable (perhaps due to overheating)

Adhesive Bond Samples

- **Test piece models all three connections (but no electrical breaks)**
  - Sector termination
    - rectangular to round transition
  - Capillary Termination
    - small to large diameter transition
  - Exhaust Termination



- **Samples prepared for several tests**
  - Pressure testing
  - Irradiation
  - Thermal cycling
  - Black anodized to simulate worst possible bond

Adhesive Bond Test Setups

Fas-Test Fitting Setup

- **Pressure Testing**
  - Tested at 100 psi (6.5 bar) using Fas-Test fittings
  - Pressurized with N2 gas - pressure decay measured
  - Tested before and after irradiation

C3F8 Pressure Vessel

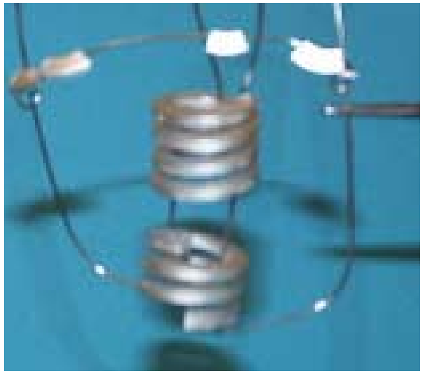
- **Irradiation**
  - Samples exposed to 3 Mrad in liquid C3F8
  - Leak rates measured before and after irradiation
  - Thermal cycling will also be tested

Adhesive Bond Pressure Test Results

- **10 Samples made for irradiation - 10 samples made for thermal cycling**
  - All samples saw 500psi without gross leak
  - Irradiation samples tested in setup before and after
  - Thermal cycling samples tested in setup before and after
  - Sensitivity on order of 10^-6 Torr-l/s with long test
- **Conclusions**
  - Adhesive joints worked well but did not pass Thermal Shock test
  - adhesive failure seems to be cause, intend to change surface prep to Phos-ano, or chromic acid etch (from appearance black)
  - Design of new termination geometry with new fittings aimed at alleviating thermally induced stresses
  - Would like to improve sensitivity of setup to speed testing and improve statistics

Corrosion Tests on Al in C3F8

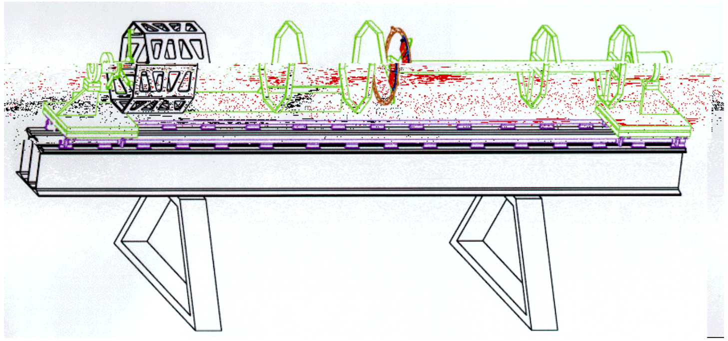
- **Sector Tubing (3003) was placed in liquid C3F8 and irradiated to 3 Mrad**
  - Two sample sizes
    - Large coil - approximately 1.5 grams
    - Small section - approximately 0.05 grams
  - Samples were held off of the bottom of containment vessel with SS wire, in order to insure complete contact with C3F8
  - Masses were measured with high precision balance numerous times on different days and averaged
  - Some evidence of Polymerization seen at level of sensitivity-- mass increase 1 part in 10^4
  - No Corrosion Seen

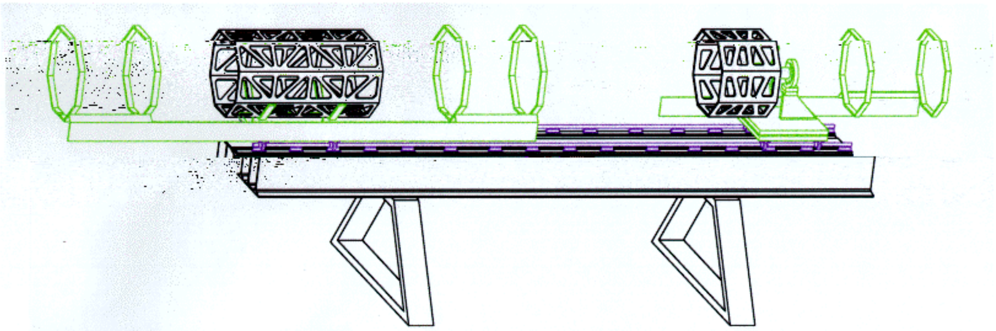


Large coil suspended by SS wire

Pixel Detector

Assembly Tooling (1.1.1.1.3.7 / 8)





- **Full sequence available on Web**
  - Ref: http://www-atlas.lbl.gov/~goozen/assdetset.html
- **Same fixturing can be used for Assembly of disks into frame as assembly of frame elements**
- **Layout gives estimate of necessary space**
  - Support frames (green) are necessary to support distended services prior to attaching to frame
- **1.1.1.1.3.7 and 1.1.1.1.3.8 do not include tooling or effort for final installation at CERN**

Test Equipment 1.1.1.1.3.9

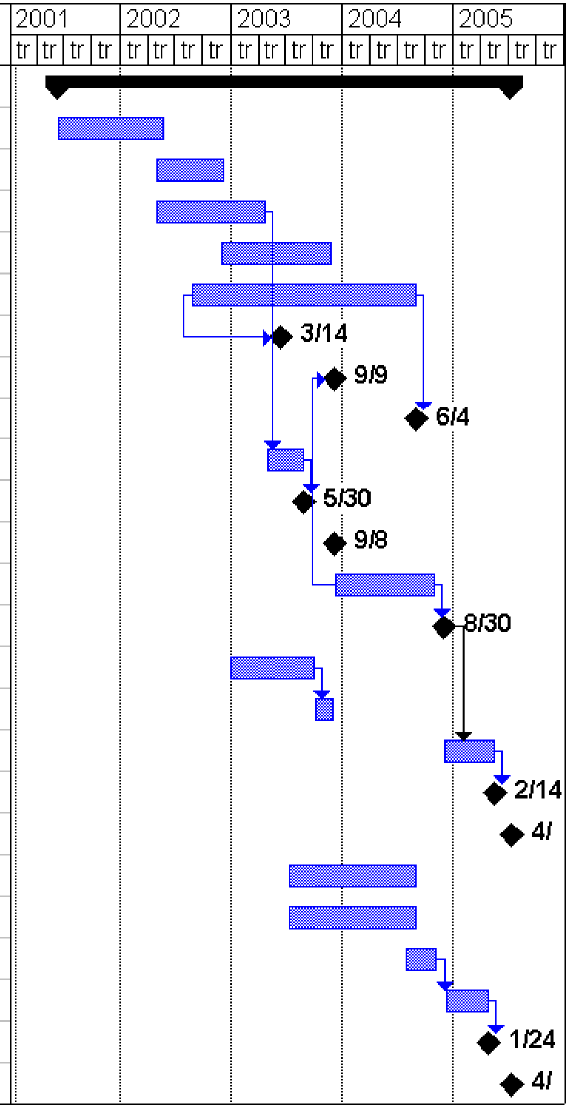
- **Equipment mostly in hand**
- **This includes an IR Camera for Sector QA**
  - Currently borrowing camera
- **Environmental chamber for thermal loading and TV holography measurements**

Installation 1.1.1.1.3.10

- **This effort occurs primarily at CERN**
- **Tooling and equipment brought by institutes to CERN**
- **Cost assumes a Level of Effort**
  - Send Technicians, Engineer to CERN for duration of installation

Pixel Detector Schedule

WBS	Task Name
1.1.1.1.3	**Production**
	Disk Sector Fab/Test
	Disk Support Ring Fab/Test
	Support Frame Fab/Test
	Thermal Barriers Fab/Test
	Outer Services Fab/Test
	Services Compl. For Initial Cryo/Hall Installation
	Services Complete for Initial Assembly
	All Outer Services Complete
	Trial Outer Structure Assembly
	Outer Structure Complete/Ready for Modules
	Outer Structure Needed for Modules
	Disk Assembly/Test
	Disk System at CERN
	Fab services supports
	Trial assembly services supports
	Outer System Assembly/Test at CERN
	Outer System Ready for Installation
	ATLAS need date for outer system install
	B-Layer Structures Fab
	B-Layer Specific Services Fab/Test
	B-Layer Assembly in Europe
	B-Layers Assembly at CERN
	B-Layer Ready for Installation
	ATLAS need date for B-Layer install



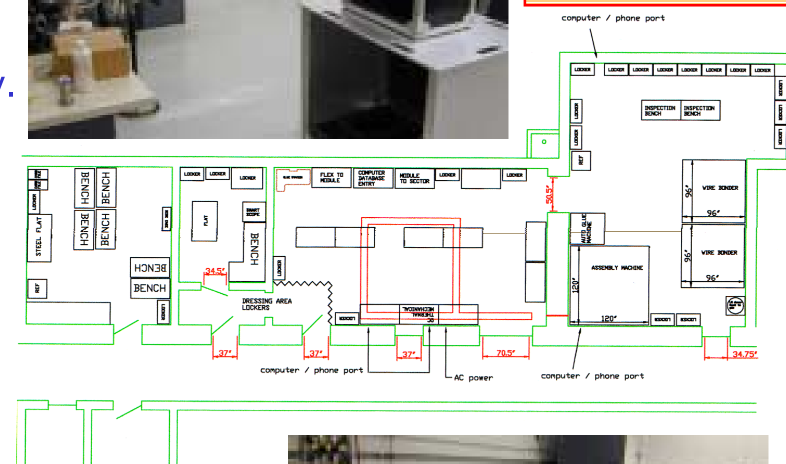
- **Schedule assumes a fully insertable system installed at latest possible date**
- **Want to Start Sector Production 3Qtr '01**

Pixel Detector

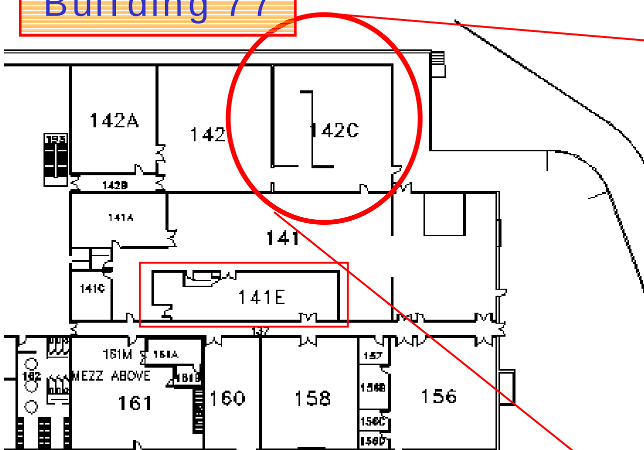
Infrastructure--Clean Space

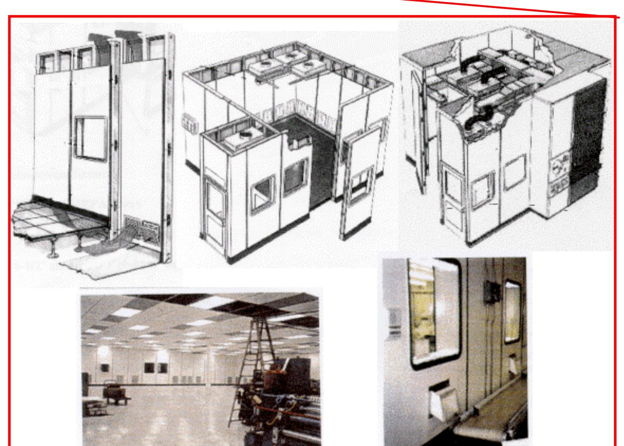
- **LBNL has been adding clean space for assembly activity**
- **Building 50 clean room 150m²**
  - completed
  - currently used for sector QA and Module assembly tasks--shared with SCT Silicon Assy.
- **Building 77 clean room 150m²**
  - Online April '01--improves / replaces 77-141E
  - Contract in place for prefab downdraft cleanroom--synchronized with 77-retrofit
  - Mechanical Assembly Sectors and Final

Building 50



Building 77



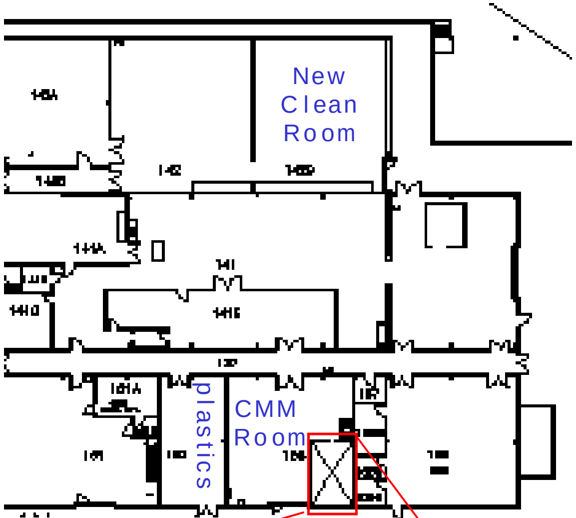


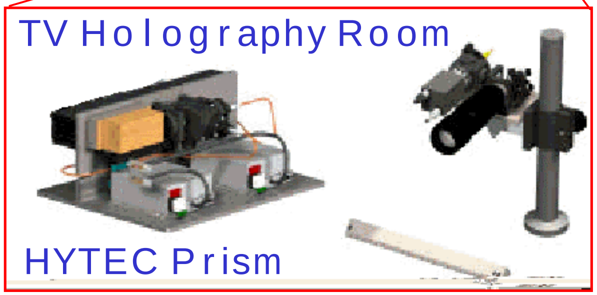
Pixel Detector

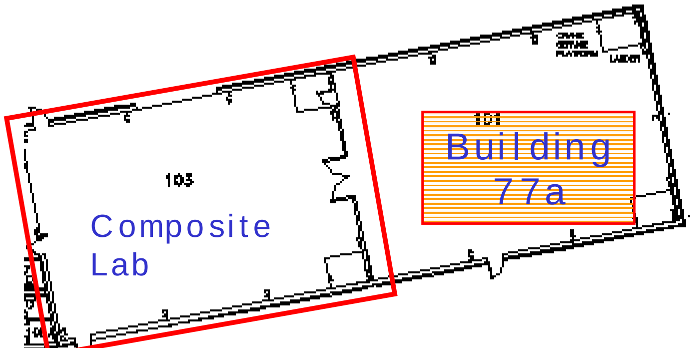
Infrastructure--Capabilities

- **LBNL is developing infrastructure in the key areas of composites and metrology**
  - Infrastructure efforts mesh well with ATLAS schedule
- **Composites Manufacturing Laboratory**
  - Major Equipment purchase mid-00, online early FY01
- **TV Holography**
  - Equipment installed, relevant personnel trained next week
- **IR imaging**
  - Well developed capability at LBNL--ATLAS is strengthening assets with equipment acquisition
  - IR imaging for project occurs in 50 cleanroom (previous slide)

Building 77







77a is across street from CMM room ~50ft

U.S. ATLAS E.T.C.
WBS Profile Estimates

Funding Source: All **Funding Type:** Project 10/24/00 8:48:03 PM

Institutions: All

WBS Number	Description	FY 96 (k$)	FY 97 (k$)	FY 98 (k$)	FY 99 (k$)	FY 00 (k$)	FY 01 (k$)	FY 02 (k$)	FY 03 (k$)	FY 04 (k$)	FY 05 (k$)	Total (k$)
1.1.1.1	Mechanics and Final Assembly	0	0	0	0	0	911	620	708	250	96	2586
1.1.1.1.1	Design	0	0	0	0	0	599	226	144	128	34	1131
1.1.1.1.1.1	Prototype Design	0	0	0	0	0	136	0	0	0	0	136
1.1.1.1.1.2	Production Design	0	0	0	0	0	463	226	144	128	34	995
1.1.1.1.2	Development and Prototypes	0	0	0	0	0	113	84	0	0	0	197
1.1.1.1.2.1	Disk Sectors	0	0	0	0	0	17	0	0	0	0	17
1.1.1.1.2.2	Disk Support Rings	0	0	0	0	0	0	0	0	0	0	0
1.1.1.1.2.3	Support Frame	0	0	0	0	0	20	0	0	0	0	20
1.1.1.1.2.4	Thermal Barriers	0	0	0	0	0	13	0	0	0	0	13
1.1.1.1.2.5	Services	0	0	0	0	0	64	84	0	0	0	148
1.1.1.1.2.6	Disk Assembly	0	0	0	0	0	0	0	0	0	0	0
1.1.1.1.2.7	Final Assembly and	0	0	0	0	0	0	0	0	0	0	0
1.1.1.1.2.8	Test Equipment	0	0	0	0	0	0	0	0	0	0	0
1.1.1.1.3	Production	0	0	0	0	0	199	310	565	122	62	1258
1.1.1.1.3.1	Disk Sectors	0	0	0	0	0	117	28	0	0	0	145
1.1.1.1.3.2	Disk Support Rings	0	0	0	0	0	0	126	0	0	0	126
1.1.1.1.3.3	Support Frame	0	0	0	0	0	0	122	122	0	0	243
1.1.1.1.3.4	B-layer Support	0	0	0	0	0	0	0	26	37	0	64
1.1.1.1.3.5	Thermal Barriers	0	0	0	0	0	0	0	0	0	0	0
1.1.1.1.3.6	Services	0	0	0	0	0	0	21	290	0	0	311
1.1.1.1.3.7	Disk Assembly	0	0	0	0	0	0	11	83	0	0	94
1.1.1.1.3.8	Disk Region Final Assembly	0	0	0	0	0	0	0	42	50	0	92
1.1.1.1.3.9	Test Equipment	0	0	0	0	0	82	2	2	7	7	100
1.1.1.1.3.10	Installation	0	0	0	0	0	0	0	0	28	56	83

ATLAS

Pixel Detector

Profile Baseline with additional Thermal Barrier